

PALEOZOIC AND MESOZOIC STRATIGRAPHY
OF NORTHERN GROS VENTRE MOUNTAINS
AND MOUNT LEIDY HIGHLANDS, TETON
COUNTY, WYOMING

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Reprinted for private circulation from
THE BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
Vol. 31, No. 9, September, 1947



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BULLETIN
of the
AMERICAN ASSOCIATION OF
PETROLEUM GEOLOGISTS

SEPTEMBER, 1947

PALEOZOIC AND MESOZOIC STRATIGRAPHY OF NORTHERN
GROS VENTRE MOUNTAINS AND MOUNT LEIDY
HIGHLANDS, TETON COUNTY, WYOMING¹

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ABSTRACT

The northern Gros Ventre Mountains and Mount Leidy Highlands area is in western Wyoming south of Yellowstone National Park. This area was a shelf zone bordering a deeper part of the Rocky Mountain geosyncline during the Paleozoic and Mesozoic eras. Therefore, the sediments deposited were relatively thin as compared with those on the west and southwest. The rocks range from pre-Cambrian to Tertiary in age, with all of the systems present, excepting possibly the Silurian. The Paleozoic strata are about 3,500 feet thick, and the Mesozoic about 12,000 feet.

INTRODUCTION

Location.—The northern Gros Ventre Mountains and Mount Leidy Highlands are in western Wyoming south of Yellowstone National Park. Together they form the eastern margin of Jackson Hole, the intermontane valley which is

¹ Part of a dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the University of Michigan.

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During the field work, which was carried on in the summers of 1944 and 1945, Camp Davis, the University of Michigan Rocky Mountain Field Station, was used as a base. The writer greatly appreciates the cooperation of the Camp Davis staff and particularly the assistance of Professor R. L. Belknap. In addition, assistance was given in the field by Camp Davis students: Ann Livesay, Lysbeth Fisher, Robert Christman, Margaret Pendleton, Jean Holford, Ruth Bachrach, and others. Professor A. J. Eardley, director of geological field work at Camp Davis, deserves special thanks for aid in the field work and in the preparation of the manuscript. Professor L. B. Kellum, director of the Museum of Paleontology, University of Michigan, aided in identifying Cretaceous fossils and in writing the section on Cretaceous stratigraphy. Professor W. F. Hunt, chairman of the department of mineralogy, University of Michigan, checked some of the thin sections and offered suggestions on part of the manuscript. Professor K. K. Landes, chairman of the department of geology, University of Michigan, made many helpful suggestions. Professor J. E. Thornton, of the English department, College of Engineering, University of Michigan, assisted greatly in the preparation of the manuscript.



bordered on the west by the Teton Range. The Mount Leidy Highlands are generally considered to include the area between the Gros Ventre River and Buffalo Fork from the eastern border of Jackson Hole to the western margin of the Wind River Mountains. Mount Leidy, the highest peak (10,317 feet), is near the center of the area. The section of the Gros Ventre Range here discussed is south of the Gros Ventre River in the Mount Leidy and Grand Teton quadrangles.

In general, the strata crop out in the eastern third of the Grand Teton Quadrangle and the western half of the Mount Leidy Quadrangle, as shown on the United States Geological Survey topographic sheets.

The drainage of the region is into the Snake River, which flows southwestward through Jackson Hole. The principal streams from south to north are Flat Creek, the Gros Ventre River, Spread Creek, and Buffalo Fork (Fig. 5).

Purpose.—The data here presented are part of a more inclusive study of the northern Gros Ventre Mountains and Mount Leidy Highlands made during the summers of 1944 and 1945. Since this area has recently become of much interest in the exploration for oil, the information may be useful to petroleum geologists and others in correlating formations and in determining the Paleozoic and Mesozoic history of western Wyoming.

STRATIGRAPHIC COLUMN
(Tertiary formations not included)

<i>Age</i>	<i>Formation</i>	<i>Thickness (Feet)</i>	<i>Lithology</i>
Upper Cretaceous	Mesaverde	4,075 ±	Characterized by massive tan sandstone cliffs capped by ledges of more resistant red-brown sandstone; interbedded shales and a few lithographic limestones
Upper Cretaceous	Cody shale	1,365	Coal beds, shales, interbedded sandstones, and a few thin nodular limestones; many beds fossiliferous
	Frontier	2,750	Tan sandstones with some interbedded shales; many fossiliferous beds
	Mowry shale	1,070	Siliceous shales, salt-and-pepper sandstone, porcellanite, and bentonite beds
	Thermopolis shale	318	Black shale and argillaceous sandstone
Lower Cretaceous	Cloverly	240-365	Variegated shales and clays with sparkly quartz sandstones and gray lithographic limestones
Upper Jurassic	Stump sandstone	350 ±	Greenish sandstones with some interbedded siltstone and shale; probably contains glauconite
Middle Jurassic	Twin Creek limestone	475 ±	Gray limestone and shaly limestone with some interbedded gray to buff shales; several fossiliferous zones
Lower Jurassic	Nugget sandstone	150 ±	Orange, cross-bedded sandstone; prominent cliff-former

STRATIGRAPHIC COLUMN—(continued)

Age	Formation	Thickness (Feet)	Lithology
Lower Triassic	Thaynes and Woodside	950 ±	Red shales and siltstones with several gray limestone beds
	Dinwoody	235	Tan and gray siltstones, tan sandstone, and limestones; some beds fossiliferous
Permian	Phosphoria	195 ±	Phosphatic shale, limestone, and chert beds
Pennsylvanian	Tensleep	300 ±	Alternating sandstones and limestones; sandstone light gray to buff; massive and cross-bedded in places; limestones white to light gray; fine-grained to lithographic
	Amsden	400 ±	Red shales and siltstone, gray limestone and sandstone; contains Darwin sandstone member
Middle and Upper Mississippian	Brazer limestone	1,000 ±	Dark gray limestone; finely crystalline to dense; cherty in places
Lower Mississippian	Madison limestone		Gray limestone; fossiliferous, commonly cherty
Devonian	Darby	325 ±	Brown limestones and dolomites with a few interbedded shales; commonly thin-bedded
Ordovician	Bighorn dolomite	300-400	Buff dolomite; massively bedded; weathers with coarsely pitted and fretted surface; upper 25 or 30 feet white, dense limestone called Leigh member
Upper Cambrian	Boysen	102-181	Gray limestone; oölitic in places; cliff-former
Middle Cambrian	Gros Ventre	539-586	Red and green shales with a little interbedded sandstone; contains prominent limestone member, Death Canyon
Middle Cambrian	Flathead quartzite	240 ±	Tan and white quartzitic sandstone; conglomeratic near base
Pre-Cambrian			Granite gneiss and pink and white granite; some granite pegmatitic

PRE-CAMBRIAN

There are only a few exposures of pre-Cambrian rock in the northern Gros Ventre Mountains. The most easily accessible of these is along Nowlin Creek, where granite, gneiss, and schist crop out. Although the relationship can not be clearly seen in this area, the granite is probably intrusive into the gneiss and schist.

Very little has been written concerning the pre-Cambrian in this and neighboring areas. St. John³ states that "the rocks at the western end of the Gros

³ F. V. Hayden, *Eleventh Annual Report of the U. S. Geol. and Geog. Survey of the Territories Embracing Idaho and Wyoming for 1877* (1879), p. 475.

Ventre Range consist chiefly of much distorted gneissic and schistose ledges." Nelson and Church⁴ show a little pre-Cambrian in the Gros Ventre Range on their geologic map and indicate in the stratigraphic column that it consists of gneiss and schist intruded by granite. In the neighboring Teton Range Horberg⁵ reports that "The main body of the pre-Cambrian is made up of steeply dipping gneisses and schists which have been intruded by pegmatite, granite and basic dikes, probably in the order named."

Specimens of granite gneiss, white muscovite-biotite granite and pink muscovite granite were collected near Nowlin Creek. The granite is believed to occur as intrusions which cut the gneiss, because in places it is very coarse-grained, almost pegmatitic, and because an intrusive relationship of the granite to the country rock is reported in other parts of the Gros Ventre Range.⁶ The principal minerals in the granite gneiss are quartz, microcline, oligoclase, and muscovite with a little zircon, apatite, and garnet and with some alteration to kaolinite, sericite, and chlorite. In the white granite the essential minerals are quartz, oligoclase, microcline, muscovite, and biotite with tourmaline, apatite, titanite, and zircon as accessories. Kaolinite, chlorite, and sericite are the alteration products. The pink granite consists of microcline, oligoclase, quartz, and muscovite. Accessory minerals are zircon and apatite. The alteration products are kaolinite, sericite, and limonite.

CAMBRIAN

General description.—Rocks of the Cambrian system crop out in the southeastern part of the Gros Ventre River area. The Flathead quartzite, Gros Ventre, and Boysen formations are present. The Flathead quartzite is dominantly quartzite and sandstone, commonly quartzitic conglomerate near the base and grading upward into quartzite and then sandstone. Some of the upper sandstones have shale interbedded. The Gros Ventre formation is dominantly green and red shale with a little interbedded sandstone, except for the Death Canyon member, which is dark gray, buff-mottled limestone. The Death Canyon member forms a prominent cliff, above and below which are shale slopes. Flat-pebble conglomerates are characteristic of the upper part of the Gros Ventre. The uppermost formation is the Boysen, which consists of cliff-forming limestones (Fig. 1).

Detailed description.—Outcrops of the Cambrian system in the Gros Ventre River area are almost inaccessible or are not clearly exposed. A partial section was measured along a tributary of Sheep Creek but since it was found to be very much like a more complete Cambrian section measured by Jean Holforty near

⁴ Vincent E. Nelson and Victor Church, "Critical Structures of the Gros Ventre and Northern Hoback Ranges, Wyoming," *Jour. Geol.*, Vol. 51, No. 3 (1943), pp. 154 and 145.

⁵ Leland Horberg, "The Structural Geology and Physiography of the Teton Pass Area, Wyoming," *Augustana Library Pub.* 16, p. 13. Rock Island, Illinois (1938).

⁶ Vincent E. Nelson and Victor Church, *op. cit.*, p. 145.



FIG. 1.—Limestone cliffs of Boysen formation exposed near mouth of Sheep Creek.

Granite Falls in the Gros Ventre Range, 16 miles southeast of the Sheep Creek locality, only the Granite Falls section is here described.

BOYSEN FORMATION

<i>Unit</i>	<i>Thickness (Feet)</i>
27. Limestone, medium gray on fresh surface; weathers dark gray with tan, sandy mottlings; beds from $\frac{1}{4}$ to 1 foot thick; clay partings.	15.2
26. Limestone, gray, weathers dark gray; finely crystalline; beds 2-10 inches thick; forms massive cliff; contains small, flat brachiopods.	32.3
25. Limestone, gray, weathers blue-gray; color varies from light gray to dark gray, mottled; mostly massive with some ledges 2 feet thick; contains brachiopods and oölites in streaks; base of oölite zone is 3 feet above the base.	11.9
24. Limestone, gray, weathers purplish; thin-bedded with clay partings; crinkly, irregular bedding surfaces.	49.2
23. Limestone, gray, weathers bluish gray; massive beds up to 3 feet thick; contains a few interbedded, thin-bedded layers.	34.0
22. Limestone, medium gray; weathers tannish; average thickness of beds 2 inches; is thinner-bedded 11.2 feet below top and near base; contains calcite crystals and is coarsely crystalline; contains oölites near top.	38.1
Total thickness of Boysen limestone.	180.7

GROS VENTRE FORMATION

Unit	Thickness (Feet)
21. Limestone, gray, weathers tannish; massive beds 2 feet thick; finely crystalline; contains solution cavities.	35.0
20. Limestone, gray, weathers medium gray; has sandy or shaly partings; sub-lithographic, contains some calcite crystals.	15.0
19. Limestone, sandy shale and shale; limestone is platy; shale is greenish gray.	32.0
18. Shale, black-green, weathers tannish; contains a few limonitic, sandy, rusty weathering zones; thin-bedded; fragments of trilobites, but rock is too much jointed to contain good specimens.	24.5
17. Covered; probably shale.	25.0±

DEATH CANYON MEMBER

16. Limestone, dark gray to black; weathers gray to dark bluish gray with brownish or rusty-mottled streaks and patches; finely crystalline to sub-lithographic; contains some calcite veins; thin-bedded, beds $\frac{1}{2}$ -5 inches in thickness; average thickness about 2½ inches; cliff-former; cliffs weathered rounded and rather pitted.	175.0
15. Covered, probably shale; in one place appears to be olive-green, paper-thin shale.	82.3
14. Limestone, dark gray to black, weathers blue-gray with brownish mottlings; mottlings are very sandy; contains sandy lenses and calcite veins; beds are 2-12 inches thick, averaging 6 inches; finely crystalline to sub-lithographic; cliff-former; weathers more angularly than cliffs above.	111.3

LOWER PART OF GROS VENTRE FORMATION

13. Sandstone, yellow-tan; beds 6 inches to 2 feet thick; very calcareous; may contain poorly preserved brachiopods; weathers into angular blocks and slabs.	13.0
12. Covered, probably shale.	7.3
11. Shale, black, fissile; contains poorly preserved trilobites and worm borings.	2.6
10. Sandstone, red-brown, weathers tan; micaceous; may be arkosic; massive, very resistant; weathers with rounded edges; no fossils.	1.3
9. Sandstone and shale interbedded; shales are grayish, weather rusty; both are friable and fissile; sandstone beds are reddish brown and 1-8 inches thick.	4.0
8. Shale, green friable; no fossils.	2.5
7. Shale, green, very micaceous or chloritic; fissile, weathers badly but not as much as unit 5; contains worm borings and poorly preserved trilobites.	1.2
6. Shale, red, almost purple; friable; apparently hematitic.	1.8
5. Shale and sandstone; shale is green and micaceous or chloritic; much weathered and friable; does not split along even planes; contains many rusty-colored weathered zones; inarticulate brachiopods, many worm borings and a few trilobites; beds so weathered that fossils are poorly preserved, a few $\frac{1}{2}$ -inch lenses of black shale which are not as much weathered as the green shale; $3\frac{1}{2}$ feet above base of unit is 1-inch bed of hard, resistant, reddish sandstone, containing no fossils; 5 feet above base of unit is another 1-inch sandstone, reddish brown, highly micaceous, and no fossils; $6\frac{1}{2}$ feet above base of unit is hard, red sandstone, $1\frac{1}{2}$ -2 inches thick and more resistant than lower two.	10.3
4. Shale, black, weathers tan or rusty; varying amounts of mica; very thin-bedded and fissile; small inarticulate brachiopods, small trilobites up to $\frac{1}{4}$ inch in size, tails of larger trilobites, worm borings? and several unidentified markings or fossils; weathered rusty-colored zones about every 3 inches vertically; also contains peculiar colonies of algae?	2.0
3. Shale, green, weathers green with brown patches; much mica or chlorite; does not split easily along planes; may contain inarticulate brachiopods; only a little exposed in creek.	.2
2. Covered, probably shale.	40.0±

Total thickness of Gros Ventre formation. 586.3±

FLATHEAD FORMATION

1. Quartzite, sandy in thin lenses; white to light gray, weathers buff to tan; coarse-grained; fractures easily in several directions along non-parallel planes; cross-bedded; beds 6 inches to 3 feet thick, but even massive beds may lense out entirely in 20 feet horizontal distance; sand grains are well rounded and apparently pure quartz; higher in section quartzite weathers reddish in spots; near top of section appears grayer and weathers darker gray; grades horizontally from coarse-grained to fine-grained.	86
(Only upper part of Flathead exposed)	

Total thickness of Cambrian measured. 853 +

Another section was measured by Holforty about 15 miles west of the Sheep Creek section on Glory Mountain in the Teton Range. For comparison, this section is also described.

<i>Unit</i>	<i>Thickness (Feet)</i>
11. Covered; small amount of thin-bedded limestone at top.....	20
10. Limestone, finely crystalline to coarsely crystalline; light gray to variegated on fresh surface; weathers gray to brown, pinkish, yellow, and purplish; contains calcite crystals in places, with some interbedded soft, yellow, calcareous shales; weathers with some rusty mottled patches and contains fucoids and poor trilobite remains; fossils scarce; limestone is oölitic in places; unit very thin-bedded for most part; beds 1-4 inches thick.....	82.1
f. Limestone; like sub-unit (e) but no pebbles and no black calcite crystals.....	14.7
e. Limestone, like Death Canyon limestone; has rusty-mottled patches and irregular bedding surfaces; contains some limestone; pebbles near base of unit; pebbles rounded and composed of calcite crystals which are dark gray to black; limestone is massive-bedded, dark gray.....	16.2
d. Limestone, gray, weathers white, finely crystalline; massive.....	6.6
c. Limestone and shale; massive ledges of oölitic limestone with a few very thin calcareous gray shales at top.....	11.8
b. Limestone, thin-bedded, $\frac{1}{4}$ inch thick; small oölitic.....	11.4
a. Limestone, fine to coarse; interbedded with some soft yellow calcareous shales.....	21.4
Total thickness of Boysen formation.....	102.1

GROS VENTRE FORMATION

9. Shale, gray-green, paper thin; weathers light gray, apparently contains no fossils; contains a few ledges of buff shaly sandstones which weather yellow-white; a few ledges of a flat-pebble conglomerate composed of limestone pebbles in limestone cement; upper ledges have more shaly cement; also contains a few ledges of light gray limestone weathering white to gray; limestone is sub-lithographic; first ledge of pebble conglomerate in limestone cement is 57 feet above base of unit; ledge is about 2 inches thick; second ledge of conglomerate in calcareous to shaly cement is 68 feet above base; ledge is 4 inches thick upper 8 feet of unit is gray-green shale interbedded with some conglomerate of limestone pebbles and a few 1- to 2-inch ledges of light gray limestone.....	78.0
8. Shale and limestone; gray-green shale and dark gray finely crystalline limestone which weathers medium gray to buff.....	29.7

DEATH CANYON MEMBER

7. Limestone, medium gray to dark gray on fresh surface, weathers dark gray, with rusty and sandy-colored mottled spots; sub-lithographic to coarsely crystalline; beds 1 inch to 2 feet thick, average 4 or 5 inches; locally may contain a few limestone pebbles; contains calcite crystals; contains a few worm? trails.....	222.4
f. Limestone; contains exceptional amount of calcite crystals; coarsely crystalline.....	32.8
e. Limestone, very limonitic, with shale intervals.....	22.8
d. Limestone, dark gray, weathers buff; regular bedding surfaces.....	29.2
c. Limestone.....	29.8
b. Limestone, brecciated and somewhat fragmental.....	9.1
a. Limestone like above.....	98.7
6. Shales, gray-green to black, weather light gray-green; very thin-bedded, rusty-stained in places; many trilobite and brachiopod remains.....	14.0
5. Limestone, dark gray to light gray, weathers medium gray to buff and tan; irregular mottlings and a few shale and sandy partings; bedding surfaces and weathered surfaces very irregular; limestone is finely crystalline.....	59.9

LOWER PART OF THE GROS VENTRE FORMATION

4. Sandstone and shale; sandstone at base; tan, weathers buff; fine-grained; thin-bedded; overlain by shale; shale overlain by sandstone, gray and fine-grained; weathers whitish; both sandstones have calcareous cement.....	30.3
3. Partly covered; partly green shale, glauconitic; shale is fissile to friable and highly weathered in places; weathers gray-green with limonitic mottlings; contains worm tubes and brachiopods.....	26.2

Unit

Thickness
(Feet)

2. Shales and sandstone interbedded; shales green, glauconitic, or chloritic and glistening; highly weathered, fissile to friable; red shales are hematitic, very sandy and oölitic in places; weather dark red to purplish and are more consolidated than Granite Creek red shales; some yellowish limonitic shales very highly weathered and friable; sandstones, hematitic, dark red on fresh surface and weather dark red to purple; form massive ledges 2 feet thick; few shaly gray-green and chloritic sandstones; very thin-bedded; a few tan sandstones, brown on fresh surface, fine-grained; beds 1 foot thick; massive ledges of sandstone, dark green and glistening on fresh surface; weather black-green . . .	77.9
j. Sandstone, hematitic; separated from green sandstone by thin shale	1.5
i. Sandstone, dark green	0.5
h. Shale, green and red	4.7
g. Sandstone, dark green	2.5
f. Shale, hematitic, oölitic and green; friable	5.0
e. Sandstone, red, hematitic, massive	1.5
d. Shale; interbedded yellow limonitic, red hematitic, and green shale	12.6
c. Sandstone, red; hematitic; massive	1.5
b. Shale, red and green; sandy and friable; highly weathered and grading into thin-bedded shaly sandstone	19.4
a. Shale and sandstone; gray-green shale; tan and red-brown sandstones interbedded; shale is very friable	28.7
Total thickness of Gros Ventre formation	538.4

FLATHEAD QUARTZITE

1. f. Sandstone; whitish on fresh surface, weathers dark gray to brown; very fine-grained	31.9
e. Sandstone; dark gray with hematitic and limonitic streaks; fine-grained and cross-bedded; 2-inch shale bed about 30.3 feet below top of unit	42.3
d. Sandstone; fine-grained; gray-tan on fresh surface, weathers gray-brown; weathers with small limonitic specks on surface	12.4
c. Sandstone, medium-grained with a few lenses of coarse quartz grains; lenses not continuous; white to buff on fresh surface, weathers dark tan to red-brown	88.0
b. Quartzite, fine-grained, grading into sandy phase	14.9
a. Conglomerate, basal; white to tan on fresh surface, weathers tan or buff; quartzitic; composed of white quartz grains, sub-angular to rounded; largest grains $\frac{1}{4}$ - $\frac{3}{4}$ inch in diameter; beds massive, 1-3 feet thick; breaks into angular blocks along fractures; fractures easily; cross-bedded	50.0
Total thickness of Flathead quartzite	239.5
Total thickness of Cambrian	880

On Sheep Creek only the upper part of the Gros Ventre formation and the Boysen could be measured. The Flathead quartzite is present, but not well enough exposed to obtain a section. The Boysen is at least 162 feet thick, thus corresponding more closely in thickness with the Granite Falls section (180 feet) than with the Glory Mountain section (102 feet). Also, lithologically it is more like the Granite Falls section. The limestones of the Boysen on Sheep and Granite creeks have clay partings, contain little or no shale, are cliff-makers, have many fossils, are platy because of thin bedding and brittleness, and commonly have a white to purple cast. In contrast, the Boysen on Glory Mountain has no clay partings, is a poor cliff-maker because of shaly intervals and shaly limestone, contains few fossils, and is generally gray to brown.

The Death Canyon member on both Glory Mountain and at Granite Falls is separated into two limestone units by a thin shale unit. On Glory Mountain the

shale is so thin that the Death Canyon ordinarily forms one prominent cliff, but in the Granite Creek area this shale has thickened so that the Death Canyon limestone forms two prominent cliffs with a shale slope between.

Terminology and correlation.—The confusion in Rocky Mountain Cambrian terminology is well known to students of the subject. It is not the purpose of this paper to correct the situation, but only to show the relationship of the new sections to those previously measured.

The lowest unit of the Cambrian section in western Wyoming is a formation consisting mainly of quartzite or quartzitic sandstone and sandstone. This group of beds was originally named the Flathead quartzite by Peale.⁷ It has since been referred to in Wyoming and Montana as the Flathead formation, the Flathead sandstone, and the Flathead sandstone member. In this paper the original term Flathead quartzite is used.

Overlying the Flathead quartzite is a series of shales containing a prominent limestone member. The strata were named the Gros Ventre formation by Blackwelder.⁸ The type section was measured on Double Top Peak in the Gros Ventre Range. When Miller⁹ measured the Cambrian section in Death Canyon in the Teton Range, he recognized the Gros Ventre formation and named the prominent limestone unit the Death Canyon member of the Gros Ventre formation. The Death Canyon member is both overlain and underlain by shales which have sometimes been referred to as the lower shale member and the upper shale member. However, when Fenton and Fenton¹⁰ remeasured the Death Canyon section, they referred to the Death Canyon member as the Death Canyon facies, and the shales below as the Wolsey formation (a term from the Little Belt Mountains, Montana), and the upper shale zone as the Lower Maurice formation (from a section on Bear Tooth Butte, Montana), and did not retain the name Gros Ventre. The present writer, believing that the term Gros Ventre has a definite meaning in this area and that the Death Canyon member is an easily recognized unit, uses these names. However, it is realized that the Wolsey shale as described by Deiss¹¹ in Yellowstone Park is probably equivalent to the lower Gros Ventre shales. The Meagher limestone, a prominent limestone above the Wolsey shale in Montana, seems to be correlative with the Death Canyon member, and the Park shale which overlies the Meagher limestone may be the equivalent of the upper Gros Ventre shales (Fig. 2).

⁷ Albert C. Peale, "The Paleozoic Section in the Vicinity of Three Forks, Montana," *Bull. U. S. Geol. Survey* 110 (1893), p. 20.

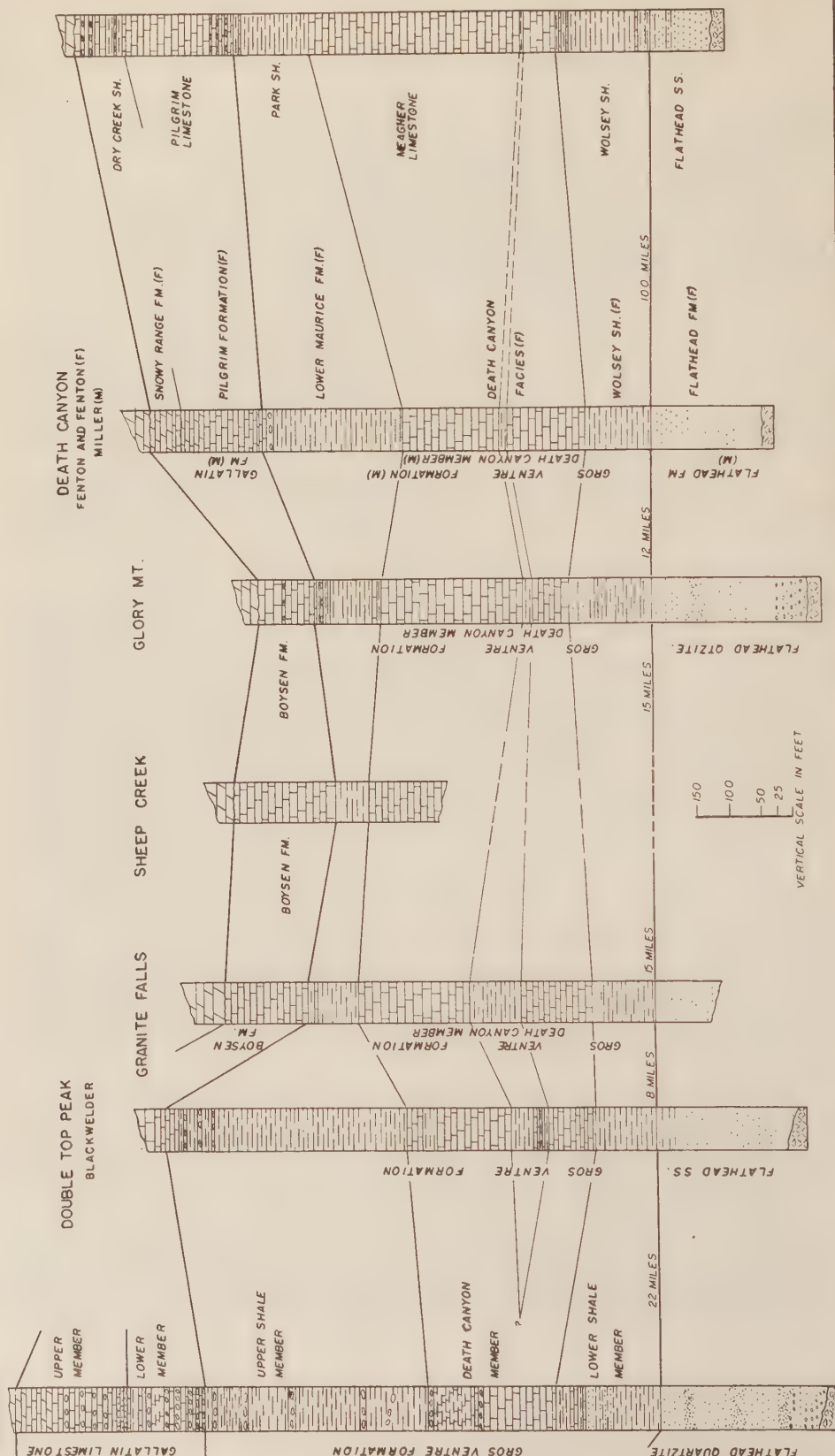
⁸ Eliot Blackwelder, "New Geological Formations in Western Wyoming," *Jour. Washington Acad. Sci.*, Vol. 8, No. 13 (1918), p. 418.

⁹ Maxwell B. Miller, "Cambrian Stratigraphy of Northwestern Wyoming," *Jour. Geol.*, Vol. 44, No. 2, Pt. 1 (1936), p. 119.

¹⁰ Carroll Lane Fenton and Mildred Adams Fenton, "Pre-Cambrian and Paleozoic Algae," *Bull. Geol. Soc. America*, Vol. 50 (1939), p. 96.

¹¹ Charles Deiss, "Revision of Type Cambrian Formations and Sections of Montana and Yellowstone National Park," *ibid.*, Vol. 47 (1936), pp. 1320-22.

SHEEP MT.
RICHMOND



The Gros Ventre formation is overlain unconformably by a group of limestone beds which were referred to as the Gallatin limestone or Gallatin formation by most early writers. Deiss,¹² who has pointed out that this term should no longer be used, has substituted the name Boysen formation. The type locality for the Boysen is in Wind River Canyon. Although some recent writers have not recognized this change, the name Boysen formation is used for the uppermost Cambrian formation in this paper because Miller¹³ and others have shown that it is

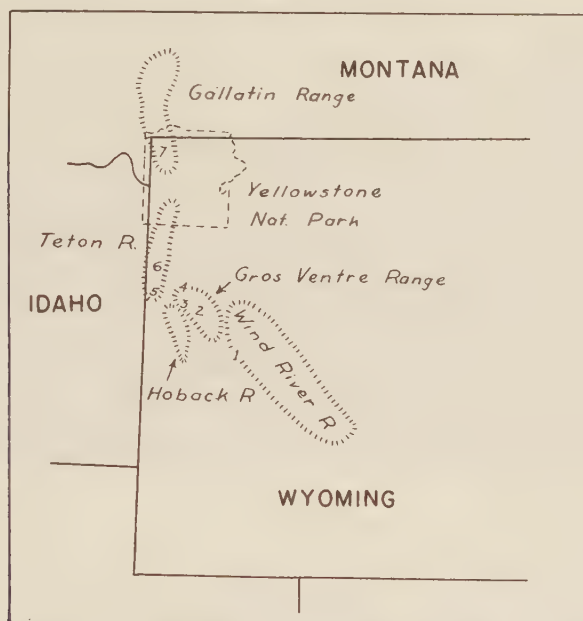


FIG. 3.—Index map showing location of Cambrian stratigraphic sections shown in Figure 2. 1. Sheep Mountain section (Richmond). 2. Double Top Peak section (Blackwelder). 3. Granite Falls section. 4. Sheep Creek section. 5. Glory Mountain section. 6. Death Canyon section (Fenton and Fenton, Miller). 7. Gallatin Range section (Deiss).

correlative with that now called Boysen in the Wind River Canyon. The Boysen of the Gros Ventre and Teton ranges probably also is correlative with the Pilgrim limestone of Yellowstone Park and Montana (Fig. 2). In the Death Canyon section, Fenton and Fenton divided these limestones into the Pilgrim and Snowy Range formations. However, in the sections measured here, no basis was observed for dividing the Boysen.

Figure 2 is intended to show the relationship of the newly presented sections

¹² Charles Deiss, "Cambrian Formations and Sections in Part of the Cordilleran Trough," *Bull. Geol. Soc. America*, Vol. 49 (1938), p. 1104.

¹³ Maxwell B. Miller, *op. cit.*, p. 123.

to others, previously measured. The correlations are based on lithologic similarity. An interesting correlation is that of the thin shale separating the limestones of the Death Canyon member. It is found to be present, but very thin, in the northwestern corner of Wyoming. Where traced southward, it thickens continually until it reaches a maximum in the Granite Creek section. It is prominent in the Double Top Peak section, but may either pinch out or perhaps was overlooked on the south in the Sheep Mountain section.

In summary, it may be stated that the sections presented here do show that the Cambrian in the Teton and Gros Ventre ranges is divisible into at least three distinct lithologic units which can be recognized over considerable distances and thus are properly considered formations. The Death Canyon member of the Gros Ventre formation also is a distinct member, which can be traced northward into Montana and eastward as far as the Owl Creek Mountains.¹⁴

Age and unconformities.—The Flathead quartzite is everywhere unconformable on the pre-Cambrian. Paleontological evidence indicates that it is Middle Cambrian in age.¹⁵ The Gros Ventre formation is probably also Middle Cambrian although there is some uncertainty among workers about the position of the boundary between the Middle and Upper Cambrian; therefore, some of the Gros Ventre might be Upper Cambrian. Miller¹⁶ found an erosional disconformity at the top of the Gros Ventre formation in Death Canyon. The varying thickness of the Upper Gros Ventre shale as compared with the remarkably uniform thickness of the Death Canyon member and lower shale may be due to an unconformity at this position (Fig. 2).

ORDOVICIAN

Description.—The Bighorn dolomite overlies the Boysen formation unconformably. It crops out only in the southwestern part of the Gros Ventre River area near Sheep Creek and in the vicinity of Sheep Mountain. In the Sheep Mountain region it occurs in the massive cliffs like those characteristic of the Bighorn in other areas. Near Sheep Creek the massiveness of the formation is not so apparent, and it is much fractured by faulting (Fig. 4).

The exposures near Sheep Mountain were seen only from a distance, but those on Sheep Creek were examined closely. However, the complete section is not exposed. Here, as elsewhere, the Bighorn consists largely of massively bedded, buff dolomite which weathers with a characteristic "coarsely pitted and fretted surface."¹⁷ As the base of the formation was not exposed it could not be determined whether or not a basal sandstone such as occurs in the Wind River Mountains (the Lander sandstone) was present. On Glory Mountain in the Teton

¹⁴ Maxwell B. Miller, *op. cit.*, p. 120.

¹⁵ *Ibid.*, p. 142.

¹⁶ *Ibid.*, p. 129.

¹⁷ Eliot Blackwelder, "Origin of the Bighorn Dolomite of Wyoming," *Bull. Geol. Soc. America*, Vol. 24 (1913), p. 624.

Range, no definite sandstone member is present, but the dolomite is sandy near the base.

The Leigh member of the Bighorn, which is described by Blackwelder¹⁸ as "being characterized by thin, dense and brittle flaggy strata with smooth milk-white surfaces," comprises the upper 25 or 30 feet of the formation. The Leigh member is exposed north of Sheep Creek.

In the type locality the Bighorn dolomite is about 300 feet thick. Horberg¹⁹



FIG. 4.—Bighorn dolomite north of Sheep Creek where one of the Sheep Creek faults cuts across the formation.

gives a thickness of 340–385 feet for it in the Teton Range, and it is estimated to be 300–400 feet thick in the Sheep Creek area. Farther northeast in Shoshone Canyon it is 450 feet thick.²⁰

Distribution and age.—The Bighorn dolomite was originally described by Darton²¹ on the eastern slope of the Bighorn Mountains. Other workers applied the name to strata resembling it over most of Wyoming and in Utah, Idaho, and Montana. It is not present in southeastern Wyoming.²² Blackwelder studied the formation in considerable detail in the Gros Ventre and Teton ranges.

The age of the Bighorn, at least in the Gros Ventre and Teton ranges is uncertain. In the type locality, numerous fossils were found, particularly in the upper

¹⁸ Eliot Blackwelder, *op. cit.* (1918), p. 419.

¹⁹ Leland Horberg, *op. cit.*, p. 12.

²⁰ G. D. Johnson, "Geology of the Mountain Uplift Transected by Shoshone Canyon, Wyoming," *Jour. Geol.*, Vol. 42, No. 8 (1934), p. 817.

²¹ N. H. Darton, "Comparison of the Stratigraphy of the Black Hills, Bighorn Mountains and Rocky Mountain Front Range," *Bull. Geol. Soc. America*, Vol. 15 (1904), p. 304.

²² Eliot Blackwelder, *op. cit.* (1913), p. 624.

part of the formation, which indicate that it is Ordovician.²³ The study of fossils from the Wind River Range indicates that the lower part (Lander sandstone) is Upper Ordovician.²⁴ Miller also considers the upper part of the formation to be Upper Ordovician.²⁵ Blackwelder²⁶ collected a small fauna from the Bighorn in the Gros Ventre Range which was considered Upper Ordovician by Ulrich,²⁷ but placed in the Middle Silurian by Weller and Kindle.²⁸ No fossils were collected from the Bighorn in the Sheep Creek area as only a few poorly preserved, unidentifiable fossil fragments were observed. On Glory Mountain in the Teton Range a few fish remains were recently discovered in the Leigh member of the Bighorn. According to Gregory,²⁹ they appear to be arthrodire plates. The only arthrodires known which may be Silurian are a very primitive group from the Upper Silurian. Since the Glory Mountain fish plates do not resemble those of the primitive Silurian group, Gregory believes that they are probably Devonian. Thus, it seems that some of the Bighorn may be Devonian in age and it is possible that part of it may even be Silurian.

Unfortunately, fossils are very scarce and poorly preserved in the Bighorn. However, the age of this formation in the Gros Ventre and Teton ranges can not be determined until more are found. The present information suggests that either the formation called Bighorn in the Gros Ventre and Teton ranges is a different formation from the type Bighorn; or that the so-called Bighorn in western Wyoming may include more than one formation and that only part of the strata are equivalent to the Bighorn formation farther east.

SILURIAN

Strata of definite Silurian age have not been recognized in western Wyoming. However, as pointed out previously, part of the Bighorn formation may be Silurian. The fact that considerable thicknesses of Silurian rocks occur in northern Utah and southeastern Idaho gives further reason to suspect that the Silurian may be represented in western Wyoming.

DEVONIAN

General description.—The Devonian is represented by the Darby formation which overlies the Bighorn dolomite. In the northern Gros Ventre Mountains it crops out along Sheep Creek, in the high country around Sheep Mountain and along the upper part of Flat Creek. Well exposed sections of the Darby formation

²³ A. K. Miller, "The Age and Correlation of the Bighorn Formation of Northwestern United States," *Amer. Jour. Sci.*, 5th Ser., Vol. 20 (1930), p. 197.

²⁴ *Ibid.*, p. 198.

²⁵ *Ibid.*, p. 209.

²⁶ Eliot Blackwelder, *op. cit.* (1913).

²⁷ *Ibid.* (1913), p. 610.

²⁸ *Ibid.*, p. 610.

²⁹ J. T. Gregory, personal communication (1947).

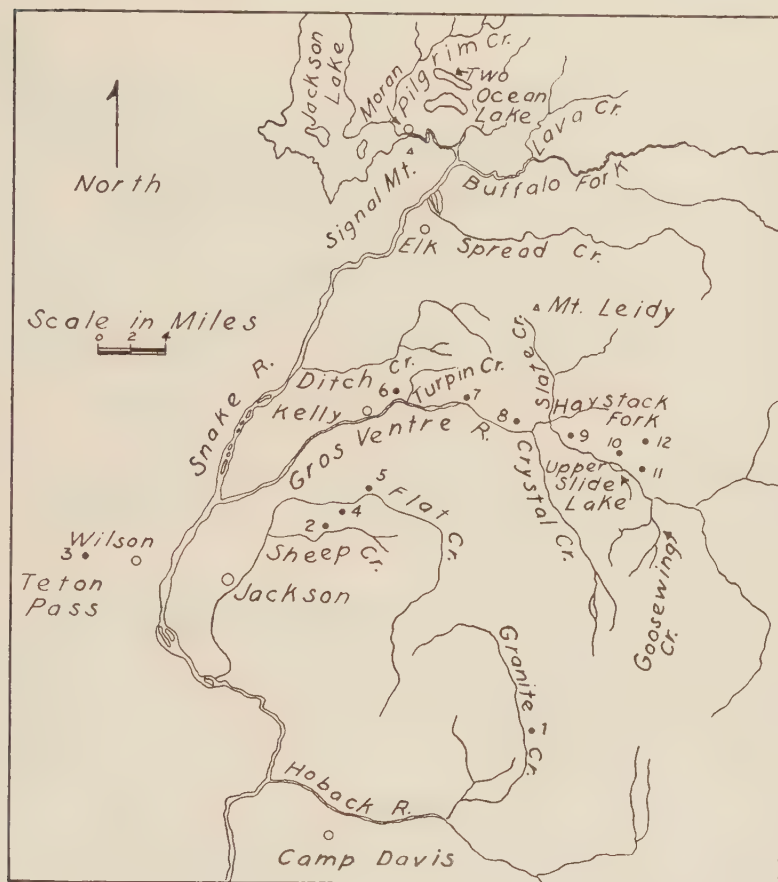


FIG. 5.—Index map showing location of stratigraphic sections. 1. Cambrian and Devonian sections on Granite Creek. 2. Cambrian section on Sheep Creek. 3. Cambrian and Devonian sections on Glory Mountain Teton Range. 4. Amsden section north of Sheep Creek. 5. Tensleep and Phosphoria sections on north side of Flat Creek. 6. Brazer section on Gros Ventre River. 7. Twin Creek, Stump and Cloverly sections on Gros Ventre River. 8. Thermopolis section and lower two units of Mowry section in Red Hills. 9. Mowry section on Gros Ventre River. 10. Frontier section on northeast side of Upper Slide Lake. 11. Cody section in Cole Hollow. 12. Mesaverde section north of Cole Hollow.

are difficult to find, as it commonly forms covered slopes between the more resistant Madison and Bighorn formations. It consists mainly of brown limestones and dolomites with a few interbedded shales. It is ordinarily thin-bedded, in many places porous and cavernous, and commonly has a petroliferous odor. It is probably about 325 feet thick.

Detailed description.—Although no complete section was measured in the northern Gros Ventre area, two detailed sections were measured by Jean Holforty at near-by localities. On Granite Creek in the Gros Ventre Range a section was obtained which has the following description.

<i>Unit</i>	<i>Thickness (Feet)</i>
48. Shale, yellowish green; thin-bedded.	Few feet
47. Limestone, brownish; very thin-bedded.	10
46. Limestone, brown; medium-grained; massive beds; very deeply pitted on weathered surface.	est. 75
45. Dolomite, light gray, weathers yellowish; fine-grained; very thin, shaly bedding.	14
44. Limestone, brown, weathers tan; fine- to medium-grained; one massive bed.	0.9
43. Dolomite, light gray, weathers tan; very sandy; a few shaly beds in unit; beds $\frac{1}{2}$ -1 foot thick.	12.5
42. Limestone, gray, weathers tan; sandy; oölitic; thin-bedded.	2.7
41. Dolomite, grayish, weathers tan; sandy; very coarse; massive beds; irregular bedding surface.	2.8
40. Covered; seems to be thin-bedded dolomite at top.	6.0
39. Limestone, brown, weathers gray to tan; fine-grained; one massive bed; very deeply pitted weathered surface near top.	9.0
38. Dolomite, gray, weathers tan; fine-grained; thin-bedded.	7.2
37. Limestone, gray-tan, weathers tan; fine-grained; sandy; beds about $2\frac{1}{2}$ feet thick.	12.0
36. Covered.	5.0
35. Limestone; much like unit 33; pitted weathered surface.	3.0
34. Dolomite, gray, weathers tan to light gray; fine-grained; hard; conchoidal fracture.	3.5
33. Limestone, brown, weathers grayish brown; medium-grained; slightly pitted weathered surface; massive beds; 11 feet above base of unit is 1.4 feet of more thinly bedded, darker gray, finer-grained limestone.	20.3
32. Limestone, light tan-gray, weathers tan; sandy; fine-grained; thin-bedded; beds are $\frac{1}{2}$ -4 inches thick; unit partly covered.	3.6
31. Limestone, brown, weathers grayish brown; medium-grained; massive beds; contains many oblong cavities on weathered surface which are not filled with calcite crystals; cavities parallel with bedding.	23.3
30. Limestone, light gray; fine-grained.	0.9
29. Shale, gray-green.	0.3
28. Dolomite, gray; dense; thin-bedded.	0.8
27. Dolomite, gray with green shaly zones.	1.1
26. Like unit 24.	0.8
25. Shale, brownish green; thin-bedded.	0.2
24. Dolomite, brownish gray; thin-bedded; finely laminated and wavy bedding planes.	1.3
23. Shale, gray-green.	0.3
22. Dolomite, gray weathers bluish gray to brown; fine-grained; very hard; conchoidal fracture in some of rock near base of unit; massive ledges at base of unit; more thin-bedded near top.	6.5
21. Limestone, light gray-tan, weathers tan; sandy; coarse-grained; only two beds in unit.	2.7
20. Limestone, dark brown to black, weathers brown in 4-foot massive ledge at base and dark gray above; fine-grained in massive ledge at base; very fine-grained to hard and dense near top; top part has splintery fracture; topmost bedding surface very irregular and deeply pitted; cavities lined with calcite crystals.	5.0
19. Dolomite, light tan-gray, weathers tan; sandy; fine-grained; beds 6 inches thick.	2.1
18. Dolomite, gray, weathers light tan-gray; soft, sandy; fine- to medium-grained; weathers in rounded cliffs; beds about 8 inches thick.	1.9
17. Dolomite, gray-green; very thin-bedded; shaly; roughly rectangular fracture; nodular near top; unit partly covered.	3.3
16. Limestone, light gray-brown, weathers tan; fine-grained; contains tiny cavities on weathered surface; calcite fillings; irregular bedding surfaces; beds about 1 inch thick.	7.6
15. Limestone, gray-tan, weathers brownish; fine-grained; contains tiny laminated parts; one massive ledge.	1.1
14. Sandstone or very sandy dolomite, light tan-gray; fine-grained; one massive ledge.	0.7
13. Dolomite, like unit 11; weathers rusty in places; a few calcareous and shaly suture-like partings.	3.0
12. Limestone, brown, weathers brownish gray; fine-grained; one massive ledge.	2.7
11. Dolomite, light gray, weathers light gray to yellow; very hard and dense; rather massive.	3.6
10. Partially covered; dolomite, gray, weathers buff; medium-grained; beds thin to 1 inch thick; limonitic stain and peculiar markings on bedding surfaces; slabby.	9.7

<i>Unit</i>	<i>Thickness (Feet)</i>
9. Limestone, dark brown, weathers grayish brown; fine-grained; fairly thin-bedded although appears massive; pitted on weathered surface near base.....	5.0
8. Shale, gray; thin-bedded; nodular; dolomitic.....	0.7
7. Limestone, dark gray, weathers dark bluish gray to medium gray; sub-lithographic; massive; irregular bedding.....	11.7
6. Partly covered; seems to contain thin, shaly dolomite.....	4.0
5. Limestone, dark gray, weathers medium gray; medium-grained; finely laminated; slabby; beds 1-10 inches thick; fossil fragments (?).....	4.7
4. Limestone, gray-brown, weathers brown; fine-grained; massive beds; minute cavities on weathered surface containing calcite crystals.....	6.2
3. Dolomite, dark gray, weathers light gray; fine-grained; thin-bedded.....	3.5
2. Dolomite, gray-brown, weathers brown; fine-grained; slight petroliferous odor; beds 2-4 inches thick.....	6.0
1. Dolomite, gray, weathers sandy colored; fine-grained and nodular; thin-bedded; beds $\frac{1}{2}$ -1 inch thick; unit partly covered.....	4.0
Total thickness measured.....	312.2

On Glory Mountain, in the Teton Range, about 15 miles west of the Sheep Creek outcrops, the following described section was obtained by Holforty.

<i>Unit</i>	<i>Thickness (Feet)</i>
28. Limestone, dense; variegated in color—yellow, pink, green; somewhat sandy; thin-bedded with very irregular bedding.....	24.0
27. Covered; probably contains thin-bedded yellow shale.....	55.0
26. Limestone, grayish brown; dense; massive to thin-bedded; irregular bedding; many cavities or solution pits on weathered surfaces; brecciated at top.....	17.5
25. Covered; top $3\frac{1}{2}$ inches are shale, yellow-green but somewhat variegated in color; thin-bedded with very irregular bedding surfaces.....	8.0
24. Limestone, yellow and somewhat variegated in color; very irregular bedding; beds 1-5 inches thick.....	6.0
23. Covered.....	5.0
22. Limestone, light gray to dark gray, weathers gray to tan; dense; thin-bedded; beds $\frac{1}{4}$ -2 inches thick.....	20.0
21. Limestone, dark gray to brown, weathers dark brown; fine-grained; beds 3 inches thick; weathers in angular blocks; strong petroliferous odor.....	3.0
20. Limestone, buff, weathers yellow; somewhat variegated in color; dense, sandy; thin-bedded; slightly irregularly weathered.....	25.0
19. Limestone, variegated in color—white to buff and red; dense; irregular bedding surfaces; pitted weathered surface.....	28.0
18. Limestone, brown.....	4.5
17. Limestone, variegated in color; very irregular bedding surfaces and many openings or pitted surfaces; beds 1-4 inches thick.....	5.0
16. Limestone, medium gray to brown; beds $\frac{1}{2}$ -4 inches thick; contains some chert and geodes with calcite fillings; weathers buff; most geodes in lower 15 feet.....	60.0
15. Covered.....	6.0
14. Shale, yellow-brown; thin-bedded.....	1.0
13. Limestone, light gray, weathers dark gray; fine-grained; massive beds.....	4.0
12. Limestone, black, weathers gray; thin-bedded; dense.....	1.0
11. Limestone, brown, weathers gray-brown; dense; massive to thin-bedded; bedding plane surfaces irregular in places; 2-foot greenish yellow, thin-bedded shale 5 feet above base of unit.....	10.0
10. Covered.....	10.0
9. Limestone, gray, weathers whitish to yellow; beds 2 inches thick; slightly irregular bedding surfaces.....	1.5
8. Limestone, black, weathers dark gray; thin-bedded.....	1.0
7. Limestone, brown; thin-bedded; cavernous.....	5.0
6. Limestone, brownish gray; dense; very irregular bedding surfaces and many cavities; beds about 10 inches thick; strong petroliferous odor; middle 5 feet is more massive, darker gray, and has more regular bedding surfaces.....	15.0

<i>Unit</i>	<i>Thickness (Feet)</i>
5. Limestone, buff, weathers tan to brown; sandy; fine-grained.	3.0
4. Shale, brownish gray; thin-bedded; sandy and soft with talc-like feel.	0.5
3. Limestone, dark gray to black, weathers bluish white; dense.	4.0
2. Limestone, brownish gray, weathers brownish gray; many solution cavities; cherty. .	7.5
1. Partially covered; limestone, medium gray, weathers light gray to buff; fine-grained; cherty in places; contains chert nodules; fairly thin-bedded; upper 2 inches dense, light gray limestone, weathers whitish.	5.0
Total thickness.	335.5

The Glory Mountain and Granite Creek sections differ considerably. On Glory Mountain, the Darby is mostly made up of gray to brown limestones with a few shale intervals, but on Granite Creek, the Darby is mainly dolomite with a few limestones. No detailed correlation between the two sections could be worked out. The Granite Creek section resembles Blackwelder's Sheep Mountain section³⁰ in that it contains numerous dolomite beds, but Blackwelder's section contains more shale.

Blackwelder³¹ states that the Darby formation is disconformable on the Leigh member, or in some places on the massive member of the Bighorn dolomite. In the two sections presented here, no definite disconformity was recognized, and the contact seemed to be somewhat gradational.

Distribution and age.—The Darby formation was named by Blackwelder³² from Darby Creek on the west side of the Teton Range. He states that the formation is present over most of northwestern Wyoming and that it has been recognized in a modified condition as far southwest as the Wasatch Range. He believes that the formation is equivalent to Peale's Three Forks shale (Montana) plus the upper part of the Jefferson limestone.

More recent work indicates that the Darby is probably not equivalent to the Three Forks.³³

The Darby formation is approximately 330 feet thick in the Teton and Gros Ventre areas. It thins in a short distance east and pinches out on the east side of the Wind River Mountains.³⁴ It thickens not far west and southwest. In the Snake River Canyon on the southwest it is more than 500 feet thick, and in southeastern Idaho Devonian rocks reach a thickness of more than 1100 feet.³⁵ In southwestern Wyoming, Devonian rocks at Labarge Mountain are more than

³⁰ Eliot Blackwelder, *op. cit.* (1918) p. 417.

³¹ *Ibid.*, p. 421.

³² *Ibid.*, p. 420.

³³ G. Arthur Cooper, "Correlation of the Devonian Sedimentary Formations of North America," *Bull. Geol. Soc. America*, Vol. 53, No. 12, Pt. 1 (1942), p. 1754.

³⁴ E. B. Branson and C. C. Branson, "Geology of the Wind River Mountains, Wyoming," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 25, No. 1 (1941), p. 129.

³⁵ Clyde P. Ross, "Geology and Ore Deposits of the Bayhorse Region, Custer County, Idaho," *U. S. Geol. Survey Bull.* 877 (1937), p. 26.

1,000 feet thick.³⁶ Love³⁷ recognized the Darby on the northeast along the southern margin of the Absaroka Range and found that the thickness was variable. One section in this area is 146 feet thick. Devonian rocks in Montana vary considerably in thickness, being more than 100 feet thick in the Phillipsburg Quadrangle.³⁸ However, their relationship to the Darby has not been studied. Few fossils have been found in the Darby, but on the basis of the information available, it is considered Devonian in age.³⁹

MISSISSIPPIAN

General description.—The Mississippian system in the Gros Ventre River area is represented by the Madison and Brazer limestones. Together they are the most prominent cliff-formers in the area. They cap Sheep Mountain and other high peaks and ridges in that vicinity. They are exposed more than 7 miles on the spur northwest from Sheep Mountain. The Mississippian also crops out on Blacktail Butte where the beds are brought up by a fault and stand almost vertically. The Madison and Brazer together are more than 1,000 feet thick.

MADISON LIMESTONE

The Madison limestone which overlies the Devonian Darby formation is typically gray in color in contrast to the brownish Darby limestones. The limestone was originally named by Peale⁴⁰ from the Madison Range in the Three Forks Quadrangle in Montana. It has since been recognized in Montana, Wyoming, Idaho, and northern Utah.

In some places the Madison contains considerable chert. It is the only Paleozoic limestone in the area being described which contains abundant fossils. It can be differentiated from the Bighorn and Darby formations by the numerous brachiopods and small cup corals which it contains. The Madison limestone is generally considered lower Mississippian in age.

BRAZER LIMESTONE

The Madison limestone is overlain by the Brazer limestone. The Brazer in northern Utah was named by Richardson.⁴¹ It has been recognized in north-

³⁶ Edward M. Kindle, "The Fauna and Stratigraphy of the Jefferson Limestone in the Northern Rocky Mountain Region," *Bull. Amer. Paleon.*, Vol. 4, No. 20 (1908), p. 6.

³⁷ John David Love, "Geology along the Southern Margin of the Absaroka Range, Wyoming," *Geol. Soc. America Spec. Paper* 20 (1939), p. 121.

³⁸ Arthur Bevan, "Rocky Mountain Front in Montana," *Bull. Geol. Soc. America*, Vol. 40 (1929), p. 471.

³⁹ Eliot Blackwelder, *op. cit.* (1918), p. 421.

⁴⁰ Albert C. Peale, "The Paleozoic Section in the Vicinity of Three Forks, Montana," *Bull. U. S. Geol. Survey* 110 (1893), p. 32.

⁴¹ G. B. Richardson, "The Paleozoic Section in Northern Utah," *Amer. Jour. Sci.*, 4th Ser., Vol. 36 (1913) pp. 407, 413.

eastern Utah, south-central Idaho, and in southwestern Wyoming. Horberg⁴² noted it in the Teton Range.

The Brazer is gray, but commonly darker gray than the Madison. It is finely crystalline to dense and is cherty in places. In some localities it is much fractured, and has networks of calcite veinlets. A limestone breccia occurs at the top of the formation in most localities. Near Sheep Creek this breccia is not present, but it is found about 5 miles north along the Gros Ventre River. The Brazer in some places contains compound corals of the *Lithostrotian* ? type. It is considered Middle and Upper Mississippian in age.⁴³

The following section of the Brazer was measured on the Gros Ventre River in the NE. $\frac{1}{4}$ of Sec. 1, T. 42 N., R. 115 W., Teton County, Wyoming, by Harold Wanless and Ruth Bachrach. The lower part of the section was not exposed here.

Unit	Thickness (Feet)
12. Limestone, brown-gray; dense to finely crystalline; irregularly brecciated at several levels; black chert and some agate.	20.0
11. Agate and sub-rounded limestone pebbles.	0.5
10. Limestone breccia, dull gray; fine-grained; agate fragments; black chert; fossil fragments.	2.0
9. Limestone rubble, gray; pieces 2 feet by $\frac{1}{2}$ foot; slightly rounded.	0.5 to 1
8. Limestone, gray; weathers pink; brecciated; lithographic; some stylolites.	0 to 1.5
7. Limestone, gray; weathers pink; oxidized to pink in upper 6 inches; lithographic; even-bedded; interrupted by unconformity.	0 to 1.5
6. Shale, red; absent in places because of unconformity.	0 to 1.5
5. Limestone, gray with red shale wash.	3.5
4. Limestone, light pink; sub-lithographic.	3.5
3. Limestone breccia, gray; fragments subangular to angular; $\frac{1}{2}$ -6 inches; includes poorly sorted pebbles, darker gray than matrix; finer-grained upward.	4.0
2. Limestone, light brown-gray; finely crystalline.	1.0
1. Limestone, dull gray; sub-lithographic; dense.	15.0
Lower units not exposed	
Total measured.	50-55

PENNSYLVANIAN

General description.—The Pennsylvanian system is represented in the Gros Ventre River area by the Amsden and Tensleep formations. There are many exposures near the Gros Ventre River and in the area on the south. The Tensleep, being a resistant formation, caps many high ridges and peaks. The famous Kelly's landslide on the Gros Ventre River occurred in Tensleep and Amsden rocks.

AMSDEN FORMATION

General description.—The Amsden formation was originally described by Darton⁴⁴ from exposures of the formation along the Amsden Branch of the Tongue

⁴² Leland Horberg, *op. cit.*, p. 16.

⁴³ Stewart J. Williams and James S. Yolton, "Brazer (Mississippian) and Lower Wells (Pennsylvanian) Section at Dry Lake, Logan Quadrangle, Utah," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 20, No. 8 (1945), p. 1150.

⁴⁴ N. H. Darton, "Comparison of the Stratigraphy of the Black Hills, Bighorn Mountains, and Rocky Mountain Front Range," *Bull. Geol. Soc. America*, Vol. 15 (1904), p. 396.

River, west of Dayton, Wyoming. It has been recognized rather widely in Wyoming and in Montana. Blackwelder,⁴⁵ while working in the Gros Ventre Range, recognized in the Amsden a prominent sandstone which he named the Darwin sandstone member.⁴⁶

The Amsden formation and its Darwin sandstone member are present in the Gros Ventre River area, but here the Darwin does not form the basal unit of the Amsden as it does where Blackwelder described it. In the Gros Ventre River area the Darwin is underlain by about 60 feet of thin-bedded, gray and pink limestones, sandstones, and shales. This lower Amsden unit rests on the Brazer formation.

The Darwin sandstone member as seen near Sheep Creek consists of about 97 feet of light gray, cross-bedded, massive sandstone. However, in exposures along the Gros Ventre River it seems to be represented by pink, brick-red, and yellow-brown sandstone with interbedded siltstones. The Darwin sandstone is overlain by 200-300 feet of upper Amsden pink-mottled limestone, red shales, and red siltstones.

Detailed description.—The Amsden section here given was measured by Wanless and Bachrach north of Sheep Creek in the NE. $\frac{1}{4}$ of Sec. 10, T. 42 N., R. 115 W., Teton County, Wyoming. The top of the Amsden is covered at this locality.

Unit	Thickness (Feet)
22. Covered	55
21. Limestone, light brown-gray; sub-lithographic	2
20. Limestone, medium gray; dense to finely crystalline; numerous fossil fragments	3
19. Covered	93
18. Limestone, dark gray; finely crystalline; solution pitted; small gray chert nodules; poorly preserved fossil fragments	1 $\frac{1}{2}$
17. Sandstone, light gray, weathers brown; hard; calcareous	1
16. Limestone, dull gray; crystalline; many crinoid stem fragments	18
15. Limestone, light yellow-gray; fine-grained; thin-bedded to 6 inches; arenaceous	12
14. Covered	2
13. Limestone, red; impure; argillaceous, arenaceous; thin-bedded	3
12. Shale, maroon to red	11
DARWIN SANDSTONE MEMBER	
11. Sandstone, light gray, weathers buff; strongly cross-bedded	93
10. Sandstone, red; thin-bedded; calcareous	4
LOWER AMSDEN	
9. Limestone, light gray; fine-grained; solution pitted; very massive	11 $\frac{1}{2}$
8. Shale, dark red; soft; very calcareous	16
7. Limestone, pink to lavender; impure; argillaceous	2 $\frac{1}{2}$
6. Limestone, light yellow-gray; sub-lithographic; splintery fracture	4 $\frac{1}{2}$
5. Limestone, dark gray; fine-grained; massive; solution pitted	3 $\frac{1}{2}$
4. Limestone, light gray; splintery fracture; lithographic	5 $\frac{1}{2}$
3. Limestone, medium gray; finely crystalline; pitted surfaces; massive	7 $\frac{1}{2}$
2. Chert, dark gray; uneven surfaces	0 to $\frac{1}{4}$
1. Unconformity	
Total thickness of Amsden formation	350

⁴⁵ Eliot Blackwelder, *op. cit.* (1918), p. 422.

⁴⁶ The Darwin sandstone was named from Darwin Peak in the Gros Ventre Mountains, but due to an error in spelling in the publication in which the name was first used it commonly occurs in print as the "Dorwin" sandstone.

Age of Amsden.—The age of the Amsden formation in this region has not been definitely determined. Fossils resembling both Mississippian and Pennsylvanian types have been collected from the lower Amsden beds. The fossil evidence seems to indicate that the Mississippian-Pennsylvanian boundary is near the base of the Darwin sandstone, but no exact contact line can be drawn.

TENSLEEP FORMATION

Description.—The Tensleep formation was originally named by Darton⁴⁷ from exposures of the formation on the west side of the Bighorn Mountains in the canyon of Tensleep Creek. In the Gros Ventre River area, it characteristically consists of alternating limestones and sandstones. The sandstones are typically light gray to buff, fine-grained, and massive. They are commonly cross-bedded. The limestones are white to light gray, fine-grained to lithographic and in many places dolomitic.

The following described section was measured by Wanless and Bachrach along Flat Creek, on its north side, in Sec. 1, T. 42 N., R. 115 W., Teton County, Wyoming.

<i>Unit</i>	<i>Thickness (Feet)</i>
15. Sandstone, light gray; fine-grained; crystalline, with calcite veins.	57
Unconformity	
14. Chert, light gray.	1
13. Limestone, white; somewhat chalky; very fine-grained; contains tan chert.	11
12. Limestone, light gray, weathers brown; coarsely crystalline; very cherty; calcite veins.	6
11. Sandstone, light gray; fine-grained; massive; calcareous; sparkly.	61
Unconformity with 1 inch relief	
10. Dolomite, light blue-gray; silty; massive; solution pitted; fucoid-like markings.	8
9. Sandstone, buff; calcareous; massive.	13
8. Limestone, light gray; dolomitic; fine-grained; massive; geoidal cavities.	13
7. Limestone, light gray, weathers white; dolomitic; sub-lithographic; highly jointed.	6
6. Sandstone, light gray, weathers red-brown; calcareous; fine-grained; firmly indurated; cross-bedded.	22
5. Sandstone, light yellow-gray; calcareous; medium-grained; somewhat friable; prominently banded; somewhat cross-bedded.	25
4. Sandstone, light yellow-gray, weathers brown; fine-grained; slightly calcareous; firmly indurated; pronounced vertical jointing.	8
3. Sandstone, light yellow-gray; medium- to coarse-grained; calcareous; sparkly; cross-bedded; irregularly laminated.	53
2. Covered.	12
1. Sandstone, buff; calcareous.	2
Total thickness of Tensleep Formation.	298

The Tensleep section which is exposed on the Gros Ventre River differs slightly from the foregoing section. It has fewer limestone units interbedded with the sandstones.

Age and correlation.—The Pennsylvanian age of the Tensleep formation has long been recognized. However, few diagnostic fossils have been found to indicate

⁴⁷ N. H. Darton, "Comparison of the Stratigraphy of the Black Hills, Bighorn Mountains, and Rocky Mountain Front Range," *Bull. Geol. Soc. America*, Vol. 15 (1904), p. 397.

its position in the Pennsylvanian system. Recent studies of microfossils from the Tensleep by Scott⁴⁸ indicate a Des Moines age for the formation in northern Wyoming and show that it is correlative with the Quadrant formation of Montana. The name "Wells formation" has been applied to the Tensleep rocks in this part of Wyoming,⁴⁹ but the Wells formation probably includes not only beds equivalent to the Tensleep but also younger Pennsylvanian rocks.⁵⁰

PERMIAN

General description.—The Permian system is represented in the Gros Ventre River area by the Phosphoria formation. It crops out on the north side of Flat Creek and in a long narrow belt which extends from the mouth of the Gros Ventre River canyon southward and eastward. The belt of outcrop crosses the valley of Crystal Creek, then continues southward and crops out in the cliffs bordering the eastern side of Crystal Creek.

In the Gros Ventre and Flat Creek localities, the Phosphoria consists mainly of cherty limestones, and dolomites, phosphatic shales, and thin sandstone and chert beds. The upper part of the formation consists of almost pure chert beds with some cherty limestone which has been called the Rex chert member.

Detailed description.—Blackwelder described the phosphate beds which make up the Phosphoria formation in the Gros Ventre River area as follows.⁵¹

Fossils are rare, except obscure pelecypods in the upper part. Being comparatively soft, these strata generally occupy saddles or ravines between ridges of the underlying sandstone and the harder Triassic red sandstone. Good exposures of them are to be found only in cliffs. . . . As usual, the phosphatic portion is near the base and within this portion there are several distinct layers of phosphate rock and phosphatic shale separated by clay shale and limestone. As in the Hoback Range, there are two principal beds of phosphate. The richer bed lies near the base, is between 5 and 7 feet thick, and consists of soft black oolite interspersed with some hard coarse-grained bands and a few seams of brownish phosphatic limestone. In this bed the content of tricalcium phosphate varies between 27 and 80 per cent, and the average content is apparently somewhat more than 50 per cent. The upper phosphate bed lies beneath a massive bed of chert, characterized by peculiar vertical tubular concretions that bear a fancied resemblance to a mass of twisted boiler tubes. This upper phosphatic bed consists largely of black or dark-gray shale with a thin layer of hard pisolitic phosphate rock at the base. The hard layer is less than 6 inches thick, but averages 56 per cent of tricalcium phosphate. The overlying shales are 40 to 45 feet thick, and their phosphate content is but 5 to 15 per cent.

Blackwelder gives a detailed section measured near the mouth of Crystal Creek on the south side of the Gros Ventre River. His section includes 288½ feet of

⁴⁸ Harold W. Scott, "Age of the Amsden Formation," *Bull. Geol. Soc. America*, Vol. 56, No. 12, Pt. 2 (1945), p. 1196.

⁴⁹ Leland Horberg, *op. cit.*, p. 16.

⁵⁰ H. W. Scott, oral communication (1945).

⁵¹ Eliot Blackwelder, "A Reconnaissance of the Phosphate Deposits in Western Wyoming," *U. S. Geol. Survey Bull.* 470 (1911), p. 468.

strata, but the upper 150 feet are probably beds included in the Dinwoody formation in this paper. Thus, the Phosphoria is probably about 138 feet thick at this locality.

Lily Marie Krusekopf and Harold Wanless measured the following Phosphoria section on the bluff on the north side of Flat Creek. The lower phosphatic zone mentioned by Blackwelder is represented by units 4 through 11. The upper phosphatic zone is represented by unit 30. Blackwelder's tubular chert concretions which resemble "a mass of twisted boiler tubes" are present in unit 37.

Unit	Thickness (Feet)
37. Chert, dark gray to black, deep red iron stains, weathers tan; hackly to brittle beds; beds 1-3 inches thick; minute shale partings; a 4-foot massive zone near middle of unit; beds thicker and more nodular at top; tubular black chert concretions 2-4 inches in diameter and bent about 40° occur just below Dinwoody contact.	50.0
36. Chert and shale, black; shale is paper-thin; more chert toward top of unit.	3.1
35. Shale, dark gray to black; paper thin layers.	9.2
34. Dolomite, black; massive; similar to unit 32.	2.5
33. Shale, black; thin-bedded; soft.	9.0
32. Dolomite, black; fetid.	1.5
31. Shale, black; thin-bedded; soft.	2.8
30. Phosphorite and shale; phosphorite in two zones each a few inches thick; not pisolitic; banded; shale between phosphorite zones, black, weathers brown.	4.0
29. Dolomite or dolomitic limestone, medium gray, weathers tan; massive; pitted; fossiliferous zone near top; calcite fills large pelecypod (<i>Pecten</i>) and gastropod (<i>Euphemites</i>) shells; vertical joints; cliff-former; more thinly bedded about 16½ feet above base of unit; darker and finer-grained near top; specimen of <i>Conularia</i> found 8 feet from top.	40.0
28. Dolomite, light gray with strip of light blue-gray chert nodules 2.5 feet from base; calcite veins and geodes; much fractured.	10.3
27. Shale, buff to yellow.	5.0
26. Siltstone, weathers tan; siliceous; thin and irregularly bedded; platy.	3.0
25. Siltstone, buff, weathers lighter buff; slightly calcareous; string of milky white chert nodules 2.3 feet above base; light blue-gray chert nodules at top; beds 1-2 inches thick at base; more massive near middle of unit.	8.2
24. Conglomerate; chert pebbles in sandy matrix.	.8
23. Chert breccia, light tan-gray, weathers tan; shaly breaks with scattered chert pebbles; calcite along joint surfaces.	11.7
Unconformity; underlying beds pitted and eroded.	
22. Dolomite, medium gray, weathers tan-gray; massive.	0-1
21. Chert, light to medium gray with iron stains; consists of flattened chert nodules, poorly cemented.	1.0
20. Shale, light gray; greenish gray oval chert nodules in upper part of unit.	2.0
19. Shale, greenish brown; soft.	5.0
18. Chert and calcite; lower 2 feet of unit thin-bedded and has wavy bands; more massive at top.	4.5
17. Dolomite, dark gray; brittle; dense; cherty; slightly petroliferous.	1.0
16. Claystone, brown; siliceous; thin-bedded; laminated; a few calcite nodules.	5.2
15. Dolomite, dark gray, weathers tan; siliceous; brittle; dense; petroliferous; conchoidal fracture.	.6
14. Claystone and dolomite, greenish brown, weathers tan; platy.	1.0
13. Limestone, yellow-brown, weathers reddish; iron-stained; dense; siliceous or argillaceous.	0.5
12. Dolomite, light to medium gray; dense; conchoidal fracture.	0.1
11. Shale, brown; poorly cemented; pisolitic; phosphatic.	0.3
10. Phosphorite, green; pisolitic; glauconitic (?).	0.2
9. Shale, green; glauconitic; pisolitic; phosphatic.	0.5
8. Limestone; phosphatic.	0.3
7. Shale, brownish gray; phosphatic.	0.3
6. Phosphorite, brownish gray; weathers bluish; pisolitic.	0.2
5. Limestone, light-colored; probably phosphatic; pisolitic; grades into phosphorite.	1.3

Unit	Thickness (Feet)
4. Phosphorite, weathers bluish white; pisolitic.....	1.1
3. Chert, light to medium blue-gray, weathers tan; brecciated in lower 2 feet of unit; cavities and veins filled with milky calcite; ledge former.....	5.5
2. Conglomerate; pebbles $\frac{1}{2}$ -2 inches in diameter; quartzite, chert and limestone pebbles in phosphorite matrix.....	0.6
1. Sandstone; conglomeratic; rounded pebbles of chert, quartzite; matrix similar to Tensleep sandstone below.....	1.6 $\pm$
Total thickness of Phosphoria formation.....	195.9-194.9

Age of Phosphoria formation.—The Phosphoria formation was named by Richards and Mansfield⁵² from exposures in southeastern Idaho. It has generally been considered as Permian in age. The economic aspects and distribution of the Phosphoria have been studied in considerable detail, but comparatively little has been done with the fauna. Girty⁵³ has made some studies of the fauna and on paleontological and stratigraphic evidence favors a Permian age. Branson⁵⁴ regards it as both Upper Pennsylvanian and Lower Permian. He believes that there is a gradation from Pennsylvanian to Permian with no stratigraphic break. Miller and Cline,⁵⁵ from a study of the cephalopods from the Phosphoria conclude that at least part of the type Phosphoria section is Middle Permian. They suggest that if fossil evidence, such as that presented by the Bransons,⁵⁶ indicates that some of the lower Phosphoria beds are of Pennsylvanian age, these beds should be removed from the Phosphoria formation and placed in a separate formation. Frenzel and Mundorff,⁵⁷ on the basis of fusulinid and other fossil evidence, concluded that the beds generally called Phosphoria are referable to more than one stage of the Permian. The beds from which they obtained fusulinids in southwestern Montana were near the base of the formation and are of Lower Permian age. The only significant fossil obtained from the Phosphoria in the Gros Ventre area was a specimen of *Conularia kaibabensis* McKee found about eight feet from the top of unit 29. This species occurs in the Middle Permian Kaibab formation in northern Arizona.⁵⁸ Thus it seems likely that at least part of the Phosphoria in this area is Middle Permian.

⁵² R. W. Richards and G. R. Mansfield, "The Bannock Overthrust," *Jour. Geology*, Vol. 20, No. 8 (1912), pp. 681-89.

⁵³ G. R. Mansfield and G. H. Girty, "Geography and Geology and Mineral Resources of Part of Southeastern Idaho, with Descriptions of Carboniferous and Triassic Fossils," *U. S. Geol. Survey Prof. Paper* 152 (1927), p. 78.

⁵⁴ C. C. Branson, "Paleontology and Stratigraphy of the Phosphoria Formation," *Missouri Univ. Studies*, Vol. 5, No. 2 (1930), p. 5.

⁵⁵ A. K. Miller and L. M. Cline, "The Cephalopods of the Phosphoria Formation of Northwestern United States," *Jour. Paleon.*, Vol. 8, No. 3 (1934) p. 285.

⁵⁶ C. C. Branson, *op. cit.*, and E. B. Branson, "The Lower Embarras of Wyoming and Its Fauna," *Jour. Geology*, Vol. 24, No. 7 (1916), pp. 639-64.

⁵⁷ Hugh Frenzel and Maurice Mundorff, "Fusulinidae from the Phosphoria Formation of Montana," *Jour. Paleon.*, Vol. 16, No. 6 (1942), p. 678.

⁵⁸ Edwin D. McKee, "A *Conularia* from the Permian of Arizona," *Jour. Paleon.*, Vol. 9, No. 5 (1935), p. 429.



FIG. 6.—Triassic redbeds of Woodside and Thaynes formations compose hills in foreground. Gros Ventre River cuts through redbeds, separating Red Butte (on right side of river) from other "Red Hills."

TRIASSIC

General description.—The Triassic in the Gros Ventre River area is represented by the Dinwoody, Woodside, and Thaynes formations. They crop out along the Gros Ventre River from Turpin Creek southeastward to Crystal Creek. The belt of outcrop widens considerably in the Crystal Creek region, and the redbeds of the Woodside and Thaynes formations form the colorful "Red Hills" (Fig. 6). Three miles south of the mouth of Crystal Creek the belt of outcrop narrows considerably but continues southward and forms cliffs along the eastern side of Crystal Creek. The Woodside and Thaynes also crop out north of the Gros Ventre River along Ditch Creek.

The Triassic beds are nearly 1200 feet thick. The lower 235 feet, which make up the Dinwoody formation, are mainly tan and gray limestones and siltstones. They are overlain by more than 950 feet of redbeds consisting mainly of shale, sandstone, and siltstone. All three formations are probably Lower Triassic in age.

DINWOODY FORMATION

The Dinwoody formation was originally described by Blackwelder⁵⁹ from outcrops of the formation in Dinwoody Canyon on the northeastern slope of the Wind River Mountains, near Du Bois, Wyoming. In the Gros Ventre River area it consists of 235 feet of tan and gray siltstones and limestones between the Phosphoria formation below and the redbeds above.

Newell and Kummel⁶⁰ have recognized three major divisions in the Dinwoody:

⁵⁹ Eliot Blackwelder, *op. cit.* (1918), p. 425.

⁶⁰ Norman D. Newell and Bernhard Kummel, "Lower Eo-Triassic Stratigraphy, Western Wyoming and Southeast Idaho," *Bull. Geol. Soc. America*, Vol. 53 (1942), p. 941.

a "basal siltstone," the "*Lingula*" zone, and an upper division, the "*Claria*" zone. According to Newell and Kummel, the lower "basal siltstone" is not present in the Gros Ventre River area probably because of non-deposition. However, the "*Lingula*" and "*Claria*" zones are present. Since Newell and Kummel have discussed the Dinwoody in some detail and have given a detailed section measured in the Gros Ventre River area, it seems unnecessary to discuss it further in this paper.

WOODSIDE AND THAYNES FORMATIONS

The Woodside and overlying Thaynes are two formations originally named by Boutwell⁶¹ in the Park City mining district of northeastern Utah. Newell and Kummel⁶² have extended the use of these names as far east as the Gros Ventre Range.

The Woodside consists of 553 feet of red shale,⁶³ siltstone and sandstone in the Gros Ventre River area. In the type locality it consists of a little more than 1,000 feet of maroon and red siltstone. Newell and Kummel⁶⁴ consider that the western Wyoming redbeds belong to the same facies as the type Woodside, but believe that they correspond stratigraphically only with about the upper half of the Woodside of the Park City area.

In the Gros Ventre River area, the bottom of the first prominent limestone in the redbed series is taken as the Woodside-Thaynes boundary. The beds above are dominantly red shales, sandstones, and siltstones with a few thin limestones. They differ considerably from the type Thaynes, which is essentially calcareous.⁶⁵ Newell and Kummel have stated that:⁶⁶

The lower Thaynes is lithologically well defined and easily recognized as far northeastward as the canyon of the Snake River in the Wyoming Range, near Hoback post office in western Wyoming. Reconnaissance observations indicate profound changes in the Thaynes in the score or so miles between this locality and sections in Hoback Canyon and Gros Ventre Canyon just east of Jackson Hole. Although time did not permit more than cursory examination of the Thaynes equivalents there appears to be a profound convergence or overlap of the Thaynes toward the north and east. . . . Near Hoback post office, on Snake River, the Thaynes includes probably 1,000 feet or more of silty limestones and buff shales, with only minor quantities of red beds. Thaynes equivalents in Hoback Canyon and Gros Ventre Canyon are apparently less than half as thick and consist principally of red beds with relatively inconspicuous purplish to white dolomitic limestones.

Since detailed sections of both the Woodside and Thaynes are given by Newell and Kummel for the Gros Ventre River area, they are not repeated here.

Because the Woodside-Thaynes boundary is very difficult to recognize in the

⁶¹ John M. Boutwell, "Geology and Ore Deposits of the Park City District, Utah," *U. S. Geol. Survey Prof. Paper* 77 (1912), pp. 52, 55.

⁶² Norman D. Newell and Bernhard Kummel, *op. cit.*

⁶³ *Ibid.*, p. 969.

⁶⁴ *Ibid.*, p. 947.

⁶⁵ John M. Boutwell, *op. cit.*, p. 55.

⁶⁶ Norman D. Newell and Bernhard Kummel, *op. cit.*, p. 948.

Gros Ventre area, the two formations were considered as one unit in mapping. In fact, in view of this difficulty and the lack of typical Thaynes lithology in the Gros Ventre River area, it might be justifiable to refer all of the redbeds now included in the Woodside and Thaynes to a single formation, the Chugwater. The name Chugwater has been used by Love and others⁶⁷ on the east side of the Wind River Mountains to include 1,000–1,250 feet of beds overlying the Dinwoody and underlying the Nugget formation. The term could be applied in the same sense in the Gros Ventre River area. Also, the Alcova limestone, which is a persistent member of the Chugwater in the Wind River area, may be present in the Gros Ventre area.⁶⁸

JURASSIC

General description.—Jurassic rocks crop out in the same general area as that of the Triassic system. They are exposed on Turpin Creek and crop out in a broad band along the Gros Ventre River southeastward to Crystal Creek. Near the mouth of Crystal Creek they swing southward, are exposed in cliffs along Crystal Creek, and make up part of the divide between it and the Gros Ventre River. Jurassic rocks are also exposed on Ditch Creek.

The Jurassic system is represented by the Nugget sandstone, the Twin Creek limestone, the Stump sandstone, and the Morrison (?) formation. The Nugget sandstone, the oldest Jurassic formation is orange to salmon-colored, cross-bedded sandstone. It is overlain by the dominantly gray shales and limestones of the Twin Creek, above which occur the greenish sandstones and shales of the Stump formation. The Morrison formation may also be represented. Since the Morrison (?) beds have not been definitely separated from the overlying Cloverly of the Cretaceous, the question of their occurrence is treated under the Cretaceous.

NUGGET SANDSTONE

The Nugget sandstone characteristically forms orange-colored cliffs in the Gros Ventre River area. It varies in color from pink to buff to orange, but is ordinarily buff or orange. It is generally massively bedded and cross-bedded in places. The sand grains are mostly small and uniform in size. They are somewhat rounded and many of them are frosted. The cement is siliceous, and in some places the sandstone is quartzitic. It is about 150 feet thick in the Gros Ventre River area but thins to the north and is only about 50 feet thick on Ditch Creek. Except for a white sandstone 3–10 feet thick, present in most localities at the base of the formation, the lithologic character varies little vertically. There are no recognizable units within the formation which can be traced laterally. As yet, no fossils have been found in it.

⁶⁷ J. D. Love, C. O. Johnson, H. L. Nace, and others, "Stratigraphic Sections and Thickness Maps of Triassic Rocks in Central Wyoming," *U. S. Geol. Survey Prelim. Chart 17*, Oil and Gas Inves. Ser. (1945).

⁶⁸ Norman D. Newell and Bernhard Kummel, *op. cit.*, p. 948.

The Nugget formation was originally named by Veatch⁶⁹ from outcrops of the sandstone in southwestern Wyoming. It is present over much of western and central Wyoming and in eastern Idaho. Along the Idaho-Wyoming boundary it is at least 1,200 feet thick⁷⁰ but it thins eastward and northward. Love and others⁷¹ state:

The Nugget is the most spectacular sandstone wedge in central Wyoming. It is 500 feet thick at the southwest margin of the Wind River Basin, thins to the north and east, and is absent in most places north of the Owl Creek Mountains and along the eastern margin of the Wind River Basin.

The Nugget sandstone is probably Middle or Lower Jurassic in age. Imlay⁷² believes that it may be Lower Jurassic because of the finding of Bajocian (lower Middle Jurassic) ammonites some distance above the base of the Twin Creek limestone. According to Baker, Dane and Reeside,⁷³ the Nugget is the equivalent of the Navajo sandstone of southern Utah.

TWIN CREEK LIMESTONE

The Twin Creek limestone overlies the Nugget sandstone. It consists mainly of gray limestones, gray to buff shales, with a little red shale and siltstone. The following section was measured about 1½ miles east of Kelly's Slide on the north side of the Gros Ventre River.

Unit	Thickness (Feet)
13. Shale and shaly sandstone; gray; soft; mostly covered	46
12. Shale; probably almost entirely greenish gray shale; lower 140-150 feet contains many <i>Gryphaea calceola</i> var. <i>nebrascensis</i> Meek and Hayden and some other fossils	178
11. Limestone, gray; massive with some fossils; oölitic	5 to 6
10. Covered; probably occupied by gray shale	37
9. Limestone, gray; lower 5 feet very finely crystalline; upper part fossiliferous and with oölitic larger than those of interval 4	21
8. Covered; probably greenish gray and red shales	95
7. Shale, dark gray; breaks into angular fragments	15
6. Limestone, bluish gray, weathers buff; argillaceous; contains <i>Pinna</i> , <i>Gervillia</i> , <i>Gryphea planconvexa</i> , <i>Modiolus subimbricate</i> White?, <i>Pleuromya</i> , <i>Comptonectes</i> , <i>Cucullae</i> , <i>Trigonia</i> , <i>Lima</i> , <i>Anatina punctola</i> (Stanton)	0.7
5. Shale, dark gray; in part calcareous; breaks into angular fragments and contains numerous pelecypods (<i>Pholadomya</i> , <i>Pleuromya</i> , <i>Astarte</i> , <i>Trigonia</i>), gastropods, a few cephalopods and brachiopods	9

⁶⁹ A. C. Veatch, "Geography and Geology of a Portion of Southwestern Wyoming and Special Reference to Coal and Oil," *U. S. Geol. Survey Prof. Paper* 56 (1907), p. 56.

⁷⁰ Joseph Neely, "Stratigraphy of the Sundance Formation and Related Jurassic Rocks in Wyoming and Their Petroleum Aspects," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 21, No. 6 (1937), p. 723.

⁷¹ J. D. Love, Harry A. Tourtelot, Chester O. Johnson, and others, "Stratigraphic Sections and Thickness Maps of Jurassic Rocks in Central Wyoming," *U. S. Geol. Survey Chart* 14, Oil and Gas Inves. Ser. (1945).

⁷² Ralph W. Imlay, "Occurrence of Middle Jurassic Rocks in Western Interior of United States," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 29, No. 7 (1945), p. 1022.

⁷³ A. A. Baker, C. H. Dane, and J. B. Reeside, Jr., "Correlation of the Jurassic Formations of Parts of Utah, Arizona, New Mexico and Colorado," *U. S. Geol. Survey Prof. Paper* 183 (1936), p. 3.

Unit	Thickness (Feet)
4. Limestone, dark gray; finely crystalline; thin-bedded in lower part and thick-bedded in upper part; contains very minute oölites.....	16 to 17
3. Covered; probably gray shale in upper part and red shale in lower part.....	18
2. Limestone, light gray; crystalline; massive; upper part finer crystalline than lower; lower part somewhat arenaceous and containing numerous rounded and angular fragments of limestone.....	28
1. Shale, grayish green and red; lower part red and arenaceous.....	5 to 6
Total thickness of Twin Creek limestone.....	473.7 to 476.7

The Twin Creek has several fossiliferous zones. Neely⁷⁴ lists a number of species collected from the Twin Creek in the Gros Ventre area. The collections from the foregoing section have not been studied yet. The outstanding fossil zone, very useful in mapping, is the *Gryphaea* zone near the top of the formation. From a distance it may be recognized as a light buff-colored shale slope, and on the outcrop it is recognized by the thousands of *Gryphaea calceola* var. *nebrascensis* which weather out of it.

The Twin Creek limestone was named by Veatch⁷⁵ from exposures of the limestone in southwestern Wyoming. Neely⁷⁶ reports a thickness of 2,800 feet for the Twin Creek in the western part of the state, but it becomes thinner on the east. Dobrovolney⁷⁷ measured 725 feet near Camp Davis. In the Gros Ventre area it is about 470 feet thick.

Imlay⁷⁸ has shown that the Twin Creek formation is probably Middle and lower Upper Jurassic in age in southeastern Idaho. The age relations of the Twin Creek in the Gros Ventre River area to that of southeastern Idaho can not be determined until the fossils are studied, but it seems likely that it is also Middle and lower Upper Jurassic. It is probably equivalent to the Gypsum Spring and part of the "Lower Sundance" of central Wyoming and to the lower Ellis formation of Montana. The first three units of the measured section are considered to be the equivalent of the Gypsum Spring formation, but they do not form an easily mapped unit.

STUMP SANDSTONE

About 250 feet of greenish sandstones and shales are placed in the Stump formation. The Preuss sandstone, which overlies the Twin Creek farther west, was not definitely recognized in this area, but it may be present because the beds at the top of the Twin Creek and base of the Stump are so poorly exposed that the lithologic character could be not clearly seen. The following section of the

⁷⁴ Joseph Neely, *op. cit.*, p. 729.

⁷⁵ A. C. Veatch, *op. cit.*, p. 56.

⁷⁶ Joseph Neely, *op. cit.*, p. 724.

⁷⁷ Ernest Dobrovolney, "Jurassic and Cretaceous Strata of the Camp Davis Area, Wyoming," *Papers Michigan Acad. Sci., Arts, and Letters*, Vol. 26 (1940, published in 1941), p. 431.

⁷⁸ Ralph W. Imlay, *op. cit.*, p. 1020.

Stump was measured about $1\frac{1}{2}$ miles above Kelly's landslide on the northeast side of the Gros Ventre River.

Unit	Thickness (Feet)
14. Shale, black and greenish black, weathers maroon; bedding about 6 inches thick. . .	4
13. Covered.	21
12. Sandstone, weathers buff; massive; medium-grained; cross-bedded; poorly cemented. .	23
11. Covered.	36
10. Sandstone, gray; massive; weathers into thin layers.	18
9. Covered; probably red and gray sandstone and shale.	43.8
8. Sandstone and shale; gray sandstone; massive, weathering into thin layers; same interbedded greenish gray shale.	21
7. Covered; probably shaly sandstone and sandy shale.	25
6. Sandstone, greenish gray; massive; cross-bedded; weathers into thin layers.	60
5. Limestone, yellowish to brownish; arenaceous; contains numerous rhynchonellids (cf. <i>Kallirhynchia myrina</i>) and some pelecypods.	0.8
4. Shale, green; arenaceous.	2
3. Sandstone, greenish gray; massive; weathers into thin layers (flagstones) with even bedding 1-3 inches thick.	23
2. Mostly covered; probably shale; may contain glauconite.	55
1. Siltstone, red; mostly covered.	15
Total thickness of Stump formation.	347.6

Note: The green-colored sandstones and shales probably derive their color largely from glauconite.

The Stump beds show considerable variation and inter-fingering laterally. It is difficult to trace horizontally any of the beds, excepting a few massive sandstones. The upper contact of the Stump is gradational, and the beds are not well exposed. The contact was arbitrarily placed below the buff and white sparkly sandstone of a type which occurs in places at several horizons in the Cloverly formation.

The Stump formation was named for Stump Peak in the Freedom Quadrangle, Idaho.⁷⁹ It was recognized by Horberg⁸⁰ in the Teton area, and although not recognized by Neely is believed to be present in the Gros Ventre River area. It is probably equivalent to what is generally termed upper Sourdance in central Wyoming and to the upper part of the Ellis formation of Montana.

It may be that the upper Stump contact should be placed lower, possibly at the top of unit 6 or 8 and that the sandstones and shales above represent the Morrison formation. However, since these beds do not form a mappable unit and are lithologically like the Stump, they were included in the Stump formation. More information is needed to prove or disprove the presence of the Morrison formation.

CRETACEOUS

General description.—The Cretaceous system in the Mount Leidy Highlands is about 9,800 feet thick. Probably about 250 feet of this is Lower Cretaceous,

⁷⁹ G. R. Mansfield and P. V. Roundy, "Revision of the Beckwith and Bear River Formations of Southeastern Idaho," *U. S. Geol. Survey Prof. Paper* 98-G (1916), p. 81.

⁸⁰ Leland Horberg, *op. cit.*, p. 20.

the remainder, Upper Cretaceous. The Lower Cretaceous sediments are probably continental whereas the Upper Cretaceous includes both continental and marine deposits.

The Lower Cretaceous crops out in a long narrow belt extending from the south-central part of the area north-northwest across the Gros Ventre River. It continues northwesterly and finally is covered by the Tertiary on the northwest side of Turpin Creek.

The Upper Cretaceous covers a broad area west and north of the Gros Ventre River and the area near Spread Creek and Buffalo Fork. It has a larger area of outcrop than any other system.

The Upper Cretaceous of this area represents neither the continental nor the deep basin facies, but is an intermediate type. The marginal facies is north and east of this area, and the region of greatest deposition is on the south. Because of this intermediate paleogeographical location of the Mount Leidy Highlands area with reference to the Cretaceous seas, it is to be expected that both continental and marine sediments would be present.

The Cretaceous beds of the Mount Leidy Highlands are more like those of the Bighorn basin and central Wyoming than those of the deep basin in southwestern Wyoming. Therefore, the terminology of the eastern and southeastern sequences has been applied.

CLOVERLY FORMATION

General description.—Overlying the Jurassic Stump formation is a series of variegated shales with some interbedded sandstone and gray lithographic limestone. The beds, which are extremely variable, generally can not be traced horizontally. They resemble beds of both the Morrison and Cloverly formations of other localities. They are called Cloverly here, mainly because there is some fossil evidence which indicates Cretaceous age. However, part of them may belong to the Morrison formation.

The following section was measured on the north side of the Gros Ventre River, about 2 miles above the Lower Gros Ventre River landslide.

<i>Unit</i>	<i>Thickness (Feet)</i>
10. Covered; probably mainly gray shales and clay beds.....	57
9. Shale, gray at base, red above with dark gray algal-like concretions; dark gray at top..	24
8. Limestone, gray with numerous gray limestone pebbles $\frac{1}{8}$ –1 inch in diameter.....	$\frac{1}{2}$
7. Limestone, slightly darker gray than the underlying limestone; finely crystalline to lithographic; high calcium content; basal part concretionary.....	9 $\frac{1}{2}$
6. Limestone, very light gray with earthy feel and conchoidal fracture; argillaceous.....	9 $\frac{1}{2}$
5. Shale, red to purple to green; algal (?) concretions present in the green beds along with botryoidal masses of chalcedony, possibly representing replacement of the calcareous algal (?) concretions.....	81
4. Shale, red; in places gastroliths (?) on surface; mostly covered.....	29 $\frac{1}{2}$
3. Sandstone, gray to white; sparkly; coarse-grained; thin-bedded; friable.....	4
2. Sandstone, yellowish brown; coarse-grained; lower part thicker-bedded than upper; several beds 1–14 inches thick; reddish and better cemented than beds of rest of interval; many chert fragments and much secondary quartz; cross-bedded.....	16
1. Sandstone, white with pink streaks; some massive and some thin-bedded; sparkly.....	6
Total.....	237

Near the Gros Ventre River Red Hills bridge, about 6 miles southeast of the foregoing locality, the Cloverly section is somewhat thicker. It is estimated to be 337-364 feet thick.

In the upper part of the formation a conglomerate is present in places. It is either not persistent or happened to be covered in the foregoing section. Where seen, it is composed mainly of well rounded light and dark gray limestone pebbles with an average diameter of $\frac{3}{8}$ inch. In some places polished quartzite pebbles more than 2 inches in diameter occur. These are like the gastroliths which weather out of the shales below. The greatest thickness observed was 10 feet.

The section of the Cloverly measured above the lower Gros Ventre landslide is considerably thinner than the section on the southeast in the Red Hills. The thickening is largely due to additional beds, mainly variegated shales, at the top of the formation, but because the beds are extremely irregular and variable throughout the formation, definite proof of erosion was not seen.

If there is a disconformity at the top of the variegated shales, it may be the boundary between the Lower and Upper Cretaceous. In any case, there is an outstanding lithologic break here, which is clearly recognizable throughout the area in which the beds are exposed.

Few fossils have been found in this formation. Highly polished quartzite and chert pebbles are common. These are identical with the so-called gastroliths which are reported from both the Morrison and Cloverly formations in other regions. They occur in the shales and also in conglomerates which are near the top of the formation in some localities.

Limestone beds of the Cloverly sequence have yielded a few very poorly preserved pelecypods. Reeside⁸¹ found a few specimens in the gray lithographic limestone above the purple shale (see unit 6 of Cloverly section). He believes that they definitely indicate Cretaceous age.

Correlation.—The variegated beds were originally called Morrison (?) in the Gros Ventre River area because of their stratigraphic position and their lithologic similarity to the Morrison formation of other areas.⁸² However, the lithologic appearance is also very much like that of the Cloverly formation of the Wind River and Bighorn basins. Also, the few fossils suggest that the beds, or at least part of them, are Cretaceous rather than Jurassic. There may be an unconformity at the top of the beds, but no evident break occurs within the series, so that it can not be divided into the two formations, the Morrison and the Cloverly. Thus, until it is established that the Morrison formation is represented, the name Cloverly seems most applicable. Love and others⁸³ in describing probably equivalent beds in central Wyoming did not divide the Morrison and Cloverly but used the two words together in naming the formation. The beds below their quartz crystal

⁸¹ J. B. Reeside, Jr., informal communication (1944).

⁸² Joseph Neely, *op. cit.*, p. 729.

⁸³ J. D. Love and others, "Stratigraphic Sections and Thickness Maps of Lower Cretaceous and Non-Marine Jurassic Rocks of Central Wyoming," *U. S. Geol. Survey Chart 13*, Oil and Gas Inves. Ser. (1945).

sandstone, which they included in the Morrison and Cloverly, may be equivalent to some of the upper sandstone and shale beds here included in the Stump.

On the basis of the invertebrate fossils found by Reeside in the Cloverly formation in the Gros Ventre River area the beds are probably Lower Cretaceous, although the lower part may be equivalent to the Jurassic Morrison. The Cloverly resembles lithologically parts of the Gannett group of the Teton and Hoback mountains. Purple and red siltstones and gray lithographic limestones are common in both formations. Also, limestone pebble conglomerates occur in the Cloverly which are almost identical with some in the Gannett. Most of the Gannett is considered to be Lower Cretaceous.⁸⁴ Stokes⁸⁵ considers the Ephraim conglomerate, the oldest formation in the Gannett group, as probably equivalent to the Morrison, but has no conclusive fossil evidence. Imlay⁸⁶ also considers the Ephraim conglomerate of the Gannett group as equivalent, in part, to the Morrison. Thus, a small part of the lower Gannett group may be correlated with the Morrison whereas the younger and larger part is probably correlated with the Cloverly.

The Cloverly formation was originally named by Darton⁸⁷ for Cloverly, a post-office on the east side of the Bighorn Basin in Wyoming. Beds of the Cloverly were described throughout the Bighorn Basin by Lupton,⁸⁸ Hewett,⁸⁹ and others and the name was applied to similar beds in the Wind River Basin. Moulton and Knappen⁹⁰ recognized the Cloverly in southern Montana.

In the Bighorn Basin the top of the Cloverly has been placed above a light-buff or tan-colored sandstone called the Greybull sandstone member. Above this sandstone member commonly occur a group of thin sandstones and shales called the "rusty beds." Hewett and Lupton⁹¹ and later Moulton and Knappen,⁹² who considered the Greybull sandstone as the top of the Cloverly formation, placed the overlying "rusty beds" in the Thermopolis shale. Others including Lee⁹³ and

⁸⁴ Raymond E. Peck, "Lower Cretaceous Rocky Mountain Nonmarine Microfossils," *Jour. Paleon.*, Vol. 15, No. 3 (1941), p. 286.

⁸⁵ William L. Stokes, "Morrison Formation and Related Deposits in and Adjacent to the Colorado Plateau," *Bull. Geol. Soc. America*, Vol. 55 (1944), p. 969.

⁸⁶ Ralph W. Imlay, *op. cit.*, p. 1020.

⁸⁷ N. H. Darton, "Comparison of the Stratigraphy of the Black Hills, Bighorn Mountains, and Rocky Mountain Front Range," *Bull. Geol. Soc. America*, Vol. 15 (1904), p. 398.

⁸⁸ Charles T. Lupton, "Oil and Gas near Basin, Big Horn County, Wyoming," *U. S. Geol. Survey Bull.* 621, Pt. 2 (1915), p. 168.

⁸⁹ D. F. Hewett, "The Shoshone River Section, Wyoming," *U. S. Geol. Survey Bull.* 541 (1912), pp. 94-95.

⁹⁰ G. F. Moulton and R. S. Knappen, "Geology and Mineral Resources of Parts of Carbon, Big Horn, Yellowstone and Stillwater Counties, Montana," *U. S. Geol. Survey Bull.* 822-A (1930), pp. 23-25.

⁹¹ D. F. Hewett and C. T. Lupton, "Anticlines in the Southern Part of the Bighorn Basin, Wyoming," *U. S. Geol. Survey Bull.* 656 (1917), p. 19.

⁹² G. F. Moulton and R. S. Knappen, *op. cit.*, p. 26.

⁹³ Willis T. Lee, "Correlation of Geologic Formations between East Central Colorado, Central Wyoming, and Southern Montana," *U. S. Geol. Survey Prof. Paper* 149 (1927).

more recently Love⁹⁴ placed the "rusty beds" in the Cloverly. In the Gros Ventre River area the Greybull sandstone has not been definitely recognized, although a thin sandstone is present in some places at the top of the variegated shales. The "rusty beds" may be equivalent to what is here called the Thermopolis shale or to the lower part of it. Thus the Cloverly of the Gros Ventre River region is probably equivalent to Hewett and Lupton's Cloverly, to the Cloverly of Knappen and Moulton, and to the lower two zones of the Morrison and Cloverly of Love and others in central Wyoming. In some places sparkly sandstones occur in the Gros Ventre River Cloverly which resemble the "quartz crystal sandstones" which occur in central Wyoming. Sparkly quartz crystal sandstones are also reported from the Kootenai⁹⁵ of south-central Montana, which has also been correlated with the Cloverly.

Figure 8 shows the probable correlation of the Gros Ventre River Cloverly with strata of other areas.

THERMOPOLIS SHALE

General description.—The Thermopolis shale overlies the variegated shales of the Cloverly formation. It consists of a group of interbedded sandstones and shales of prevailing dark color. Near the top of the formation some beds of dense gray limestone and dolomite occur. Commonly the basal beds of the formation make conspicuous cliffs above the softer and more brightly colored shales of the Cloverly. It is about 318 feet thick.

Detailed description.—The following section of the Thermopolis shale was measured on the west side of Slate Creek just above its mouth (Fig. 5). Here the formation is exposed in two prominent cliffs with covered slopes between.

<i>Unit</i>	<i>Thickness (Feet)</i>
13. Tan slope; gypsum crystals.	26½
12. Shale, sandstone and limestone; cliff-forming; bottom of cliff consists of dark gray, nodular shale and some thin-bedded shale; shale has nodules of pyrite and lenses of dense gray limestone which weather buff and rusty; top of the cliff is tan shale with slabby tan sandstones, interbedded shales and some beds of dense gray limestone; limestone weathers brown and contains mud cracks; slabby tan sandstone at top is ripple marked; sandstone in places extends down into vertical fractures in cliff.	42
11. Covered interval; probably gray shale.	36½
10. Shale with two or three ledges of dense gray dolomite; shale is dark gray to black; mostly black; weathers mainly to very fine fragments, ⅛–¼ inch in diameter; some shale beds which weather into slabs have worm trails; dolomite ledges weather rusty and black and are ½–1 foot thick.	71½
9. Shale and sandstone interbedded, dominantly shale; shales are lighter-colored (gray) near base, becoming darker and more splintery near top; some have irregular markings; near base a greenish shale; interbedded sandstones are fine-grained, almost quartzitic; some show fine laminations; unit more shaly near top; forms cliff.	52
8. Sandstone and shale interbedded; sandstone whitish, weathers buff to purplish; very irregularly bedded; forms three definite ledges, 2 feet exposed in each ledge; other sandstone beds may be covered; shales, gray to black, form gray slope; vary from splintery material to types breaking into fragments 6 inches long; irregular markings on surface; some is pitted like raindrop impressions, but deeper.	37

⁹⁴ J. D. Love, *op. cit.*, U. S. Geol. Survey Prelim. Chart 13.

⁹⁵ L. S. Gardner, T. A. Hendricks, and others, "Mesozoic and Paleozoic Formations in South-Central Montana," U. S. Geol. Survey Prelim. Chart 18, Oil and Gas Inves. Ser. (1945).

Unit	Thickness (Feet)
7. Sandstone, whitish, weathers buff to purplish; very irregularly bedded; cliff-forming; cliff face is nodular and weathers irregularly.....	4½
6. Shale, dark gray to black, weathers gray; makes gray shale slope; irregular markings....	18½
5. Sandstone and shales; sandstone is white with rust-colored grains throughout; weathers buff with pinkish tinge; massive to thin-bedded; cross-bedded; massive sandstone is cliff-former; some worm trails in sandstone at top of unit; shale, gray, weathers white in places; paper-thin.....	15½ ±
4. Sandstone, white with rust-colored grains; weathers buff with pinkish tinge; very fine-grained; cross-bedded; massive bedding, 8-20 inches thick; cliff-forming.....	4
3. Sandstone and shales interbedded; sandstone, white with rust-colored sand grains; weathers buff; very fine-grained; bedding ½-4 inches, average 2 inches; shale, gray rusty on weathered surface; thin-bedded.....	4
2. Shale, dark gray, rusty stain; thin-bedded; unit partly covered (15 inches exposed)....	5 ±
1. Sandstone, light buff, weathers buff and light gray; thin irregular beds ½-¾ inch thick; weathers into slabs; irregular markings on surface resembling worm trails.....	1
Total thickness.....	318 ±

Use of name Thermopolis.—The type locality for the Thermopolis shale is near the town of Thermopolis in Hot Springs County, Wyoming. The name was applied by Lupton⁹⁶ to a mass of generally shaly rocks limited below by the top of the Greybull sandstone member of the Cloverly formation and above by the base of the Mowry shale. In the Bighorn Basin it contains a persistent sandstone member known as the Muddy sand. Since the Greybull and Muddy sandstones could not be recognized in the Gros Ventre River area, the name Thermopolis has been applied to the group of dark-colored sandstones and shales which occur between the top of the variegated shales of the Cloverly and the base of the salt-and-pepper sandstones, bentonites, and procellanites of the Mowry shale.

Thermopolis-Mowry contact.—The contact between the Thermopolis and Mowry shales, as in most other areas, is gradational. The base of the Mowry was chosen at the bottom of the first salt-and-pepper sandstone, which is a type of sandstone occurring throughout the vertical extent of the Mowry. Above this sandstone, the shales are of the Mowry type and much bentonite is interbedded. Below this sandstone no bentonite was observed. The placing of the contact here was also useful for mapping because in many places it could be recognized from a distance as the third prominent ledge above the Cloverly.

The Muddy sandstone, which is a good marker in other areas, has not been found in the Gros Ventre River area. There is a possibility that it is represented by the basal salt-and-pepper sandstone which is here included in the Mowry formation. The base of the salt-and-pepper sandstone lies about 324 feet above the base of the variegated shales. On Horse Creek on the east side of the Wind River Mountains the base of the Muddy sandstone is about 300 feet above the top of the variegated shales.⁹⁷ If the two sandstones are correlative, the 75 feet of shale and bentonite overlying the sandstone would be included in the Thermopolis shale instead of in the Mowry. However, because the correlation of the

⁹⁶ Charles T. Lupton, *op. cit.*, p. 168.

⁹⁷ John D. Love and others, *op. cit.*, U. S. Geol. Survey Prelim. Chart 13.

basal salt-and-pepper sandstone with the Muddy sandstone is problematical, and the sandstone and overlying shales are lithologically more closely related to the Mowry, it seems best, for the present, to place the upper Thermopolis contact at the base of the salt-and-pepper sandstone.

Age and correlation.—Since no fossils were found in the Thermopolis shale, its age can not be definitely determined. Its stratigraphic position and lithologic character suggest correlation with the Bear River formation of southwestern Wyoming. The nearest outcrops of the Bear River formation are along the Hoback River 15 or 20 miles from outcrops of the Thermopolis along the Gros Ventre River. The Bear River has a distinctive brackish-water fauna which is considered to be Upper Cretaceous in age.⁹⁸ Thus, this correlation suggests Upper Cretaceous age for the beds referred to the Thermopolis in the Gros Ventre area. Also, as previously discussed, there may be a disconformity at the top of the Cloverly, which marks the boundary between the Lower and Upper Cretaceous. The Thermopolis in this area may therefore represent the lowest of the Upper Cretaceous formations. On the other hand, if the basal salt-and-pepper sandstone of the Mowry is equivalent to the Muddy sandstone, according to Reeside's 1944 Upper Cretaceous correlation chart, the Muddy sandstone is at the base of the Upper Cretaceous, and the Thermopolis, then, is both Upper and Lower Cretaceous. The solution of this problem will have to await the finding of fossil evidence. However, on the basis of present knowledge, the writer considers the Thermopolis as Upper Cretaceous. Figure 8 shows a possible correlation of the Thermopolis of the Gros Ventre River area with other parts of Wyoming and southern Montana.

MOWRY SHALE

General description.—The Mowry shale in the Gros Ventre River and Mount Leidy Highlands area consists of salt-and-pepper sandstones, black and gray shale, bentonite, thin dolomites, and many porcellanite beds. From a distance it has an over-all gray appearance with distinct light and dark bands (Figure 7). The only fossils discovered were a few fish scales. It is about 1,070 feet thick.

Detailed description.—The following section of the Mowry, with the exception of the two lower units, was measured on the northeast side of the Gros Ventre River below Upper Slide Lake. The lower two units which are not fully exposed here were measured on the west side of Slate Creek a short distance above the mouth.

<i>Unit</i>	<i>Thickness (Feet)</i>
41. Covered interval; tan slope; includes black shale beds and yellow bentonite.	41
40. Sandstone, tan, lower part weathers brown, upper part weathers gray; friable and massive; some interbedded shale.	114
39. Sandstone, brown, weathers tan to brown; salt-and-pepper type; mostly massive and friable.	20½

⁹⁸ C. A. White, "The Bear River Formation and Its Characteristic Fauna," *U. S. Geol. Survey Bull.* 128 (1895), p. 24.



FIG. 7.—Banded Mowry beds overlain by ledges of Frontier sandstone exposed along Gros Ventre River.

<i>Unit</i>	<i>Thickness (Feet)</i>
38. Porcellanite or siliceous tuff and shale; porcellanite, white; occurs at base of unit; 6 or 8 inches thick; tan slope above, probably shale	22
37. Sandstone and shale interbedded; sandstones weather buff and in places maroon; blocky, forming ledges; bedding averages 8 inches thick	44
36. Porcellanite or very hard siliceous tuff; dominantly very white and some pink; some weathers rusty brown; bedding $\frac{1}{4}$ –6 inches thick; seems to be persistent and traceable bed; chalky appearance on weathered surface; veinlets of red and white SiO_2	12 $\frac{1}{2}$
35. Covered gray and tan slope; probably shales and bentonitic shales; black nodules in shales	30
34. Sandstone and shale interbedded; at bottom of unit are shales and yellow bentonitic clays overlain by smooth gray, weathered porcellanite bed 5 inches thick; above is gray, quartzitic sandstone weathering pink overlain by quartzitic sandstones, fine- to coarse-grained, separated by black and tan shale beds; sandstone beds vary from 3 to 12 inches thick	22
33. Sandstone and shales interbedded; ledges of salt-and-pepper and quartzitic sandstone interbedded with tan and black shales; some massive sandstone ledges weather reddish	65
32. Shale and sandstone; lower part is tan slope; above is black shale with white clay bed which separates it into two parts; above is 2 $\frac{1}{2}$ feet of white tuffaceous material with orange streaks; above is gray quartzitic sandstone about 5 inches thick	10
31. Sandstone and shale; sandstone weathers tan and reddish; very thin to massive bedding ($\frac{1}{4}$ –24 inches); shales, dark gray to black, thin-bedded	26
30. Sandstone, salt-and-pepper weathers tan and red; massive	5
29. Shale, gray; nodular in lower part; some thin sandy partings, commonly tan; shale in upper part weathers tan; gypsum veinlets in lower part	19
28. Sandstone, salt-and-pepper, weathers tan; some friable; middle has massive bedding with thin bedding above and below; cavernous; one 6-inch shale bed at top of massive sandstone, black	18
27. Sandstone, gray, weathers light gray; dense and quartzitic; fine-grained; bedding $\frac{1}{8}$ –3 inches; a little interbedded shale	11
26. Shale, lower part covered; upper part, black shale; bedding $\frac{1}{2}$ –1 inch; some splintery	11 $\frac{1}{2}$
25. Porcellanite, shale and sandstone interbedded; porcellanite, gray and gray and white	

<i>Unit</i>	<i>Thickness (Feet)</i>
banded; in beds 4-12 inches thick with shales between; shales, black and perhaps brown and tan; quartzitic sandstone; porcellanite and gray quartzitic sandstone weather rusty and make beds which appear blocky from distance	31
24. Shale, black, forming gray slope; splintery and thin-bedded	7½
23. Sandstone, salt-and-pepper; well cemented at bottom, becoming more friable at top; weathers brown; can be followed considerable distance as first definite sandstone ledge; massive bedding; first massively bedded sandstone	15½
22. Sandstone, light tan, weathers whitish in places; some interbedded black and brown shales and layers of gray fine-grained quartzitic sandstone; gets more shaly at top; main sandstone is light tan; very thin-bedded; in places paper-thin; weathers to tan slope in most places, but in places stands as cliff	104
21. Covered interval; tan slope; largely black and brown shale with some interbedded sandstone; about half way up gray, fine-grained quartzitic sandstone	41½
20. Shale, black and brown, splintery; makes gray slope; about third way from bottom of unit thin (¼-2 inches) sandstone beds interbedded with shale for about 4 feet; may be more interbedded sandstone; at least two and possibly more bentonite beds; yellow, but weather white	106
19. Bentonitic clay, shale, porcellanite; bentonite bed at base about 2 feet thick overlain by black splintery shale with bed of banded and speckled porcellanite at top (2 feet) . .	16½
18. Shale, black, weathers to gray slope; breaks into small splintery fragments; thin-bedded; some thin layers of sandstone interbedded	30
17. Shale and sandstone interbedded; ledges of gray quartzitic sandstone 1-4 inches thick interbedded with thin layers of shale	10½
16. Shale, black, thin-bedded; interbedded with thin sandstone layers; alternating beds ½-1 inch thick	5
15. Sandstone, gray, quartzitic, fine-grained; laminated appearance; thin-bedded	15
14. Porcellanite; plain gray	¾
13. Sandstone, gray, quartzitic; almost like porcellanite in places; thin-bedded (½-2 inches)	3
12. Shale, partly covered; black shale, rust-stained, weathers to gray slope; some thin clay partings and bentonitic clay interbedded; possibly a little sandstone	50
11. Porcellanite, gray, lower part speckled; upper part plain gray	6
10. Shale, black weathers rusty brown; dense; near top of unit is ledge of gray quartzitic sandstone; bed of yellow bentonitic clay above sandstone and shale	5
9. Porcellanite; at bottom of this interval is dense black shale weathering rusty color; porcellanite has white matrix with gray oval speckles; bedding ½-6 inches; weathers white on surface	5
8. Sandstone, gray salt-and-pepper, type; some quartzitic near top; a little interbedded shale which weathers whitish	10
7. Shale, black weathers to gray slope; contains gray bentonitic clay and has some yellow clayey material; some rust stain; 8 feet above is dense, very dark gray shale; weathers maroon; in places nodular; above is gray porcellanite bed; 6 inches exposed; above is more dense black shale, weathers maroon; thin-bedded gray sandstone occurs about 7 feet below top and is about 1½ feet thick	22
6. Sandstone, gray salt-and-pepper; weathers into white flagstones; bedding variable as in unit 4	17
5. Shale, black and calcareous; 4 inches thick; weathers rusty; fish scales present; porcellanite-like material with fish scales; 4 inches; salt-and-pepper sandstone; one 2-inch layer of brown-gray loose sand overlying salt-and-pepper sandstone; then 10 inches gray quartzitic sandstone	2
4. Sandstone, gray salt-and-pepper; weathers white, making distinct white bed recognizable from distance; laminated; some weathers to flagstone; bedding 1½-14 inches . .	4
3. Porcellanite, dark and light gray banded; bedding 1½-6 inches; some irregular markings	4
2. Shale, bentonite, dolomite and sandstone; essentially shale unit; one 1-inch thick, dark gray dense dolomite bed interbedded in shales; shales weather rusty in places and into small splintery fragments; beds which appear white at distance are very light green bentonite; beds up to 10 inches thick; fine-grained gray sandstone, probably dolomitic (might be sandy dolomite) is interbedded in shales; occurs 20-30 feet from top of unit	75 ±
1. Sandstone, salt-and-pepper	10 ±
Total	1,067 ⅓ ±

Bentonite and bentonitic clays and shales make up about 25 per cent of the Mowry shale. The beds are commonly light green or yellow on the fresh surface. Slumping is common in these beds.

The Mowry formation is well known for its siliceous shales. In the Gros Ventre River area, not only siliceous shales occur, but also porcellanite beds like those in the Aspen formation in the Teton and Hoback ranges. The porcellanites are very fine-grained, hard, bedded rocks which break with conchoidal fracture. They occur in several colors; some are plain gray, light gray-green, or white and others are white or gray with light green specks or are banded. Some have a pinkish tinge. They occur as separate beds between shales or sandstones, or they grade into siliceous shale or quartzitic sandstone. Megascopically they resemble porcelain. Dobrovolney⁹⁹ reports that microscopically they consist mainly of unweathered dust fragments of volcanic glass.

The siliceous shales are commonly dark gray on the fresh surface but weather to an exceptionally silvery gray color. They are very hard and platy and have a subconchoidal fracture. Their exceptional hardness is due to large amounts of silica.¹⁰⁰

The origin of the siliceous shales of the Mowry was studied by Rubey.¹⁰¹ He concluded that they are in some way derived from the alteration of volcanic ash. He suggests that the original ash may have been exceptionally siliceous, that it was decomposed by long exposure to sea water, and that the silica dissolved from it was precipitated by decaying organic matter.

The relations of bentonite, porcellanite, and siliceous shales have not been satisfactorily explained. It has been suggested that volcanic ash falling in sea water may have altered to bentonite while that falling in fresh water may have altered to porcellanite. Rubey¹⁰² says that "the composition of the Mowry shale and the associated bentonite is remarkably similar in the high percentage of silica, and the relative proportions of the other constituents, strongly indicating that both contained the same original material." Although many problems remain in connection with the origin of this exceptional deposit, there is little doubt that its origin is connected with volcanic ash.

Many of the sandstones of the Mowry formation are typically light gray with black specks and thus have been called salt-and-pepper sandstones. They occur throughout the vertical extent of the Mowry. Some which are resistant form prominent ledges. The Mowry gradually becomes more sandy nearer the top, and the salt-and-pepper sandstones grade into the tan, friable sandstone which characterizes the Frontier formation.

⁹⁹ Ernest Dobrovolney, *op. cit.*, p. 438.

¹⁰⁰ W. W. Rubey, "Origin of the Siliceous Mowry Shale of the Black Hills Region," *U. S. Geol. Survey Prof. Paper 154-D* (1929), p. 154.

¹⁰¹ *Ibid.*, p. 1.

¹⁰² *Ibid.*, p. 60.

Distribution and correlation.—The Mowry shale has been found in Wyoming, Montana, western South Dakota, and northern Colorado. Throughout most of Wyoming it has a thickness of 100–300 feet, which increases southwestward.¹⁰³ In western and southwestern Wyoming the Aspen shale, which is probably the equivalent of the Mowry, is locally more than 2,000 feet thick.

The Mowry in the Gros Ventre River area is transitional between the Mowry of eastern Wyoming and the Aspen shale of southwestern Wyoming. It shows considerable thickening, has the porcellanite of the Aspen farther west, but contains much bentonite and the siliceous shales which characterize the Mowry on the east.

FRONTIER FORMATION

General description.—The Frontier formation in this area is characterized by massive tan-colored sandstones and numerous ledges of resistant sandstone interbedded with tan shales. Friable argillaceous gray and tan sandstones alternate with tan shales to form long buff-colored slopes. In the lower part of the formation are several glauconitic sandstones. There are a few black shales containing poorly preserved plant material but no coal beds were observed. Some of the sandstones contain fossil marine pelecypods, gastropods, and shark teeth. The total thickness of the formation is about 2,750 feet.

Mowry-Frontier contact.—The contact between the Mowry shale and Frontier formation is gradational. As previously noted, the Mowry in this area is characterized by black and gray shales, gray salt-and-pepper sandstones, bentonite, and porcellanite beds. About 740 feet above the base of the Mowry the gray resistant sandstones become less common, and the tan, more friable Frontier type of sandstone appears. Porcellanite and bentonite beds become less common and finally are no longer present. In place of the gray and black shales of the Mowry the tan shale of Frontier type is found.

For mapping purposes, the contact between the Mowry and Frontier formations was placed at the base of a typical Frontier type sandstone, above which no bentonite or porcellanite beds were observed. The shales above are the tan-colored Frontier type whereas those below are largely black and gray. The contact might have been placed 176 feet lower, at the base of the first prominent Frontier type sandstone, but above this sandstone are numerous beds of bentonite and Mowry type shales. Also, the sandstone chosen as the base of the Frontier seemed to be more persistent and more easily recognized for mapping purposes than the lower sandstone.

Detailed description.—The following section of the Frontier formation was measured on the north side of Upper Slide Lake along the Gros Ventre River (Fig. 5).

¹⁰³ *Ibid.*, p. 1.

PERIOD	NW. END OF WIND RIVER MTS. RICHMOND	HOBACK MTS.	TETON MTS. HORBERG	GROS VENTRE MTS	CENTRAL WYOMING LOVE	BIG HORN BASIN LEE	BIG HORN BASIN HEWETT & LUPTON	SOUTHERN MONTANA KNAPPEN & MOULTON	PERIOD
CRETACEOUS	MOWRY AND THERMOPOLIS	ASPEN	ASPEN	MOWRY	MOWRY SHALE MEMBER MUDDY SS. MEMB. SHALE MEMBER UPPER ZONE (RUSTY BEDS) MIDDLE ZONE LOWER ZONE ? MORRISON	BENTON UPPER SS UPPER SHALE MIDDLE SS. MIDDLE SHALE LOWER SS. DAKOTA GROUP	MOWRY THERMOPOLIS SHALE MUDDY SS. SHALE THERMOPOLIS GREYBULL SS VARIEGATED SHALE &	MOWRY THERMOPOLIS GREYBULL SS VARIEGATED SHALE &	MOWRY
		BEAR RIVER	BEAR RIVER	CLOVERLY					
	CLOVERLY	BEAR RIVER	BEAR RIVER	CLOVERLY	CLOVERLY	CLOVERLY	CLOVERLY	CLOVERLY	CLOVERLY
	MORRISON	GANNETT	GANNETT	CLOVERLY	MORRISON & CLOVERLY	MORRISON	MORRISON	MORRISON	MORRISON
JURASSIC	SUNDANCE	STUMP	STUMP	STUMP	UPPER SUNDANCE	SUNDANCE	SUNDANCE	SUNDANCE	SUNDANCE

Fig. 8.—Correlation chart for Lower Cretaceous and part of Upper Cretaceous.

Unit	Thickness (Feet)
27. Sandstone and covered; lower half covered tan slope, probably friable sandstone and shale; then ledge of more resistant sandstone crops out; gray, weathers somewhat maroon; covered interval, then ledge of massive sandstone; above gray, friable sandstone interbedded with more resistant blocky, brown and maroon weathering sandstone ledges; no fossils noted.	153
26. Sandstone and oyster coquina; lower bed is an oyster coquina about 4 feet thick; above is barren, cross-bedded, tan friable sandstone, weathers cavernously and forms prominent ledge on hillside; 5-6 feet exposed; above is another oyster coquina about 2 feet thick overlain by cross-bedded tan friable sandstone about 1 foot thick; then another coquina about 1-1½ feet thick overlain by more cavernous, cross-bedded sandstone; above are two 3-inch layers of oysters on top of cavernous tan sandstone; contains <i>Ostrea soleniscus</i> Meek ? var. (young form), <i>Ostrea</i> sp. A, <i>Mesostoma</i> cf. <i>M. occidentalis</i> Stanton, unidentified gastropod and unidentified pelecypod.	36½
25. Sandstone and covered; sandstone, gray-brown, weathers brown, friable and argillaceous; crops out at base; about 2 feet exposed; thin-bedded; averaging ¼ inch; slope above covered, probably shale and sandstone.	68½
24. Covered interval; tan slope; probably shale with some friable sandstone.	261½
23. Sandstone and shales; sandstone, gray, weathers brown and gray; thin-bedded (average ¼ inch); weathers into slabs; interbedded shales are gray; top of unit is gray, fine-grained sandstone, weathers orange-brown and breaks into big slabs; prominent ledge near top of hill.	18
22. Covered interval; lower part covered; probably gray shale with some interbedded sandstone; upper part gray shale, making gray slope; upper 300 feet of shale exposed.	750
21. Sandstone and shales, partly covered; shales at base; sandy shales becoming more sandy at top and with some sandstone ledges cropping out at top; some of sandstones contain <i>Inoceramus</i> and other shells; some thin-bedded and some more massively bedded; sandstone at top cavernous; salt-and-pepper sandstones make tan slope.	870
20. Sandstone, brown, weathers reddish in places; friable, thin to massive bedded, thin-bedded at top; cross-bedded; cliff-former.	25
19. Sandstone, brown, friable with two ledges of gray, hard sandstone interbedded; gray sandstone, weathers red.	21½
18. Sandstone, brown, weathers tan; very friable; cross-bedded; massive to thin-bedded; coarse-grained.	32½
17. Shale and conglomerate; shale, black; overlain by conglomerate consisting of pebbles ½-1½ inches in diameter; matrix coarse salt-and-pepper sandstone; pebbles largely gray chert with some pink quartzite and a little white, severely weathered limestone; grades above into coarse sandstone; shark teeth sparsely present. (There may be another conglomerate below the shale, but poorly exposed).	1
16. Covered, probably sandstone and some shale; 2 feet oyster coquina in about middle of of unit; contains <i>Ostrea</i> sp. D, <i>Lima</i> ? sp. B. and <i>Cardium</i> sp. aff. C. -- ? Meek.	39
15. Sandstone, gray and tan, weathers with a maroon cast; irregularly thin-bedded and cross-bedded; contains <i>Inoceramus</i> ? which are 7 inches long and 5½ inches wide.	4½
14. Sandstone and shale; covered interval probably consisting of thin-bedded sandstone and perhaps some shale; thin-bedded sandstone above containing <i>Inoceramus</i> ? fragments; probably some black shale in covered interval above; one ledge of massive tan cross-bedded sandstone overlain by thin-bedded tan and gray sandstone.	71
13. Sandstone; at base a thin bed of coarse sandstone with a few fossils; above is 3-inch ledge of gray, quartzitic sandstone; a massive tan sandstone full of <i>Inoceramus</i> fragments stands out as ledge; above are thin-bedded sandstones.	17½
12. Sandstone ledges; tan to gray; mainly thin-bedded, but some bedding 6-8 inches thick; cliff-former; no fossils observed.	22
11. Sandstone and shale; sandstone at base contains <i>Inoceramus</i> ? fragments, <i>Pteria gastroides</i> Meek, <i>Pteria</i> aff. <i>P. linguiformis</i> Evans and Shumard, <i>Pecten</i> sp., <i>Pholadomya</i> aff. <i>P. coloradoensis</i> Stanton, <i>Cardium pauperculum</i> Meek, <i>Tellina</i> sp., <i>Gyrodes</i> cf. <i>G. depressa</i> Meek, and unidentified pelecypods; non-fossiliferous gray sandstone above; thin-bedded; top of unit is maroon shale; breaks into small splintery fragments.	4
10. Sandstone, gray to tan, weathers tan; massive to thin-bedded; cliff-former; may contain some interbedded shale; at base of cliff are <i>Inoceramus</i> cf. <i>I. aculeplicatus</i> Stanton and <i>Cardium</i> sp., aff. C. -- ? Meek; a few <i>Inoceramus</i> fragments scattered throughout unit.	47½
9. Sandstone and shale; sandstone at base, tan, thin-bedded, contains plant fragments; above is light gray, thin-bedded sandstone overlain by black shale; above shale is thin-bedded salt-and-pepper sandstone; partly covered; may be more shales.	60½

Unit	Thickness (Feet)
8. Sandstone and shale; sandstone light gray, weathers into tan flagstones; bedding $\frac{1}{8}$ – $\frac{1}{2}$ inch; two beds of bluish maroon chunky shale, one 7 feet above bottom of unit, other 14 $\frac{1}{2}$ feet above bottom; may be other interbedded shales.	32 $\frac{1}{2}$
7. Partly covered; just below center of unit is maroon shale, weathers with bluish and maroon cast; chunky.	32
6. Shale and sandstone, partly covered; black shale near bottom containing many poorly preserved plant fragments; another black shale near top; at top a green sandstone ledge about 5 inches thick, probably containing glauconite; chunky.	17
5. Sandstone, brown, weathers brown and reddish; bottom is thin-bedded becoming massive (4–6 feet); at top is tan and thin-bedded ($\frac{1}{4}$ inch); ripple-marked near bottom; cross-bedded; rust and orange weathering clay nodules near base; rectangular jointing in some places; forms cliff at top of hill which appears reddish from distance.	41
4. Sandstone, greenish gray, weathers with light greenish cast; thin-bedded at top and bottom with some massive beds; probably contains glauconite grains; friable; 2-inch black shale at top of unit.	22 $\frac{1}{2}$
3. Sandstone, limestone and shale; thin-bedded gray sandstones with three nodular gray limestones interbedded; limestone beds 8–10 inches thick and somewhat brecciated; at top of unit is fossil bed 8–10 inches thick; weathers rusty brown and is underlain by black shale; <i>Exogyra</i> cf. <i>E. columbella</i> Meek?, <i>Lucina</i> sp., <i>Cardium pauperculum</i> Meek, <i>Mastra formosa</i> Meek and Hayden?, <i>Gyrodes depressa</i> Meek? <i>Pyropsis</i> ? sp., <i>Volutoderma</i> ? sp., unidentified pelecypods and shark teeth.	51
2. Limestone, gray, weathers rusty brown, nodular.	1
1. Sandstone and shale; sandstone tan, friable; lower beds thin-bedded about $\frac{1}{4}$ inch thick; massive beds above up to 4 feet thick; about 15 or 20 feet above bottom of unit is reddish slope formed by black-brown shale; top is thin-bedded friable tan sandstone; may be other shales interbedded.	52 $\frac{1}{2}$
Total thickness.	2,753

Hayden,¹⁰⁴ one of the early workers in southwestern Wyoming, named a prominent topographic feature composed of fossiliferous sandstones Oyster Ridge. Veatch¹⁰⁵ studied these oyster-bearing sandstones and named them the Oyster Ridge sandstone member of the Frontier formation. It was described as a group of sandstones, in places conglomeratic, with numerous specimens of *Ostrea soleniscus* and other species. In the type locality, this member is about 200 feet thick and the base is 600 feet below the top of the Frontier formation.

Units 10 through 17 of the Gros Ventre River section have many of the characteristics of the Oyster Ridge sandstone member and may be its equivalent. This group of beds is 206 feet thick. The sandstones include both massive and thin-bedded types. The massive sandstones are cliff formers. The uppermost unit (17) is conglomeratic. It consists largely of gray chert pebbles, $\frac{1}{8}$ to 1 $\frac{1}{2}$ inches in diameter. The matrix is a coarse salt-and-pepper sandstone. Units 10 to 17 are the most fossiliferous of the Frontier formation. They contain the following species: *Inoceramus* cf. *I. acutiplicatus* Stanton, *Pteria gastrodes* Meek, *Pteria* aff. *P. linguiformis* Evans and Shumard, *Ostrea soleniscus* Meek, *Ostrea* sp. B. *Ostrea* sp. C. *Ostrea* sp. D., *Ostrea* sp. F, *Ostrea* sp. G., *Pecten* sp., *Lima*? sp. B, *Pho-*

¹⁰⁴ F. V. Hayden, *Fifth Annual Report of U. S. Geol. and Geog. Survey of the Territories* (1872), p. 149.

¹⁰⁵ A. C. Veatch, "Geography and Geology of a Portion of Southwestern Wyoming and Special Reference to Coal and Oil," *U. S. Geol. Survey Prof. Paper 56* (1907), p. 65.

domya aff. *P. coloradoensis* Stanton, *Cardium pauperculum* Meek, *Cardium* sp. aff. *C.* —? Meek, *Tellina* sp., *Macra* sp., *Gyrodès* cf. *G. depressa* Meek.

This fossiliferous group of Frontier beds can be recognized throughout the area described wherever the Frontier is exposed. It forms the top of the ridge on the east side of Goosewing Creek; it also forms a ridge along the north side of Turpin Creek and is seen along the west side of Haystack Fork.

In summary, this group of sandstone beds (units 10 through 17) is probably the equivalent of the Oyster Ridge sandstone member of Veatch. It has corresponding lithologic character and thickness; in each place it is an outstanding fossiliferous horizon; and in both localities it lies considerably below the upper Frontier contact.

Unit 26 is an outstanding fossiliferous zone containing five layers of oyster coquina interbedded with sandstone. A detailed section of the unit follows.

	Feet
Sandstone, tan, containing two 3-inch layers of oysters.....	15
Sandstone, cavernous, cross-bedded.....	5
Oyster coquina.....	1-1½
Sandstone, tan, friable, cross-bedded.....	1
Oyster coquina.....	2
Sandstone, tan, friable, cross-bedded, forms prominent ledges on hillside, barren of fossils..	2
Oyster coquina.....	4
Total thickness.....	30

This unit is commonly a cliff-maker. *Ostrea soleniscus* Meek var. (young form), *Mesostoma* cf. *M. occidentalis* Meek and *Ostrea* sp. A. were collected from unit 26. Other fossils also probably from this zone are: *Pteria gastrodès* Meek, *Ostrea* sp. H, *Veniella* sp., *Cyrena* sp., *Cardium pauperculum* Meek, *Macra* ? *arenaria* Meek, *Turritella* sp. B, cf. *T. whitei* Stanton and *Gyrodès* sp.

Fossils of Frontier formation.—In general, the Frontier formation in this area seems to have three fossil zones, the lowest of which occurs about 104 feet above the base of the formation. The fossil bed which is only about 8-10 inches thick, contains the following species.

Exogyra cf. *E. columbella* Meek?
Liopistha meeki White
Cardium pauperculum Meek
Macra formosa Meek and Hayden
Turritella sp. B. cf. *Turritella whitei* Stanton
Gyrodès depressa Meek?
Pyropsis? sp.
Volutoderma? sp.
 Unidentified pelecypods
 Shark teeth

This zone is known to occur from Upper Slide Lake along the north side of the Gros Ventre River to Cole Hollow. Although it was not traced farther, it is probably present throughout the region where the lower part of the Frontier is exposed.

The second zone is that of the Oyster Ridge sandstone member. Here the fossils are found throughout a vertical interval of about 206 feet. The following species have been identified.

Inoceramus cf. *I. aculeplicatus* Stanton
Pteria gastrodes Meek
Pteria aff. *P. linguiformis* Evans and Shumard
Ostrea soleniscus Meek
Ostrea sp. B.
Ostrea sp. C
Ostrea sp. D
Ostrea sp. F
Ostrea sp. G
Pecten sp.
Lima? sp. B
Pholadomya aff. *P. coloradoensis* Stanton
Pholadomya cf. *P. coloradoensis* Stanton
Cardium curtum Meek and Hayden
Cardium sp. aff. *C. -- ?* Meek
Cardium pauperculum Meek
Tellina sp.
Mactra sp.
Gyrodes cf. *G. depressa* Meek
 Shark teeth

This zone was found in the Cole Hollow vicinity, on the north side of Haystack Fork, on the north side of Turpin Creek, and on the east side of Goosewing Creek. Since the zone is widely exposed throughout the Gros Ventre area it is a good marker.

The uppermost fossil zone occurs about 153 feet below the top of the Frontier formation. It contains several oyster coquinas which include the following species.

Pteria gastrodes Meek
Ostrea soleniscus Meek? var. (young form)
Ostrea sp. A
Ostrea sp. H
Veniella sp.
Cyrena sp.
Cardium pauperculum Meek
Mactra? arenaria
Turritella sp. B. cf. *T. whitei*
Gyrodes sp.

This zone is present in the vicinity of Cole Hollow, but has not been traced to neighboring localities.

The fauna of the Frontier formation in the Gros Ventre River area is most closely related to the fauna of the Colorado formation as described by Stanton.¹⁰⁶ At least eleven of the identified species and all of the genera in the Gros Ventre area were described by Stanton from the Colorado formation. The fauna includes species such as *Exogyra columbella*, *Cardium pauperculum* and *Turritella whitei*, which, according to Stanton¹⁰⁷ are not known to range into strata above the Colorado formation and are sufficiently abundant and widespread to be used

¹⁰⁶ Timothy W. Stanton, "The Colorado Formation and Its Invertebrate Fauna," *U. S. Geol. Survey Bull.* 106 (1893).

¹⁰⁷ *Ibid.*, p. 48.

in correlation. Johnson¹⁰⁸ in his faunal list of the Benton, includes nine species found in the Gros Ventre River area. The Benton group is equivalent to the lower part of the Colorado group.

Reeside¹⁰⁹ believes that the Frontier formation in the Bighorn Basin includes younger rocks than are present at the type locality of the Frontier in Lincoln County, Wyoming. He believes that the upper part of the Frontier is Niobrara in age. This may be true for the Gros Ventre area also, as an *Inoceramus* compared with *Inoceramus acuteplicatus*, which is listed by Hansen¹¹⁰ as a Niobrara fossil, was found in the Frontier there. A *Turritella* compared with *Turritella whitei*, which ranges from the Greenhorn through the Niobrara in age,¹¹¹ is also present in the Frontier of the Gros Ventre area.

Appropriateness of name Frontier.—The name Frontier formation was given by Knight¹¹² to a coal-bearing sandstone formation about 2,000 feet thick which is well developed near the town of Frontier in southwestern Wyoming. Later Veatch¹¹³ studied the formation and gives the thickness of the Frontier as 2,200–2,600 feet. Schultz¹¹⁴ who examined the Frontier formation and its Oyster Ridge sandstone member in Lincoln County, Wyoming, gives its thickness as 2,400–3,800 feet. Lupton¹¹⁵ says in his paper on “Oil and Gas near Basin, Bighorn, Wyoming,”

in the mapping of several coal and oil fields in the state (Wyoming) it has been found that there is generally a group of sandstone and shale beds in the middle of the Colorado shale which is the representative of the Frontier formation of Lincoln County. The individual beds, as well as the group of beds, thin eastward and disappear at about the meridian of Douglas (Wyoming). These beds of sandstone which contain the most prolific oil-bearing sands of the state, have previously been treated as individual members of the Colorado shale, but now it is proposed to consider them collectively as the Frontier formation and to name individual beds as members of this formation.

Thus, the name Frontier has continued to be used in the Bighorn Basin.

The name Frontier has also been applied in the Wind River Basin to a similar group of beds. Collier¹¹⁶ describes the Frontier formation in Fremont County and

¹⁰⁸ J. Harlan Johnson, “The Benton Fauna of Eastern Colorado and Kansas and Its Recorded Geologic Range,” *Jour. Paleon.*, Vol. 4, No. 2 (1930).

¹⁰⁹ Horace D. Thomas, “Frontier-Niobrara Contact in Laramie Basin, Wyoming,” *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 20, No. 9 (1936), p. 1194.

¹¹⁰ G. H. Hansen, “Vertical Range of the More Common Species of the Upper Cretaceous in the Western Interior,” *Jour. Paleon.*, Vol. 3, No. 1 (1929), p. 86.

¹¹¹ J. Harlan Johnson, *op. cit.*

¹¹² W. C. Knight, “Coal Fields of Southern Uinta County, Wyoming,” *Bull. Geol. Soc. America*, Vol. 13 (1903), p. 542.

¹¹³ A. C. Veatch, *op. cit.*, p. 65.

¹¹⁴ Alfred R. Schultz, “Geology and Geography of a Portion of Lincoln County, Wyoming,” *U. S. Geol. Survey Bull.* 543 (1914), p. 61.

¹¹⁵ Charles T. Lupton, *op. cit.*, pp. 170–71.

¹¹⁶ A. U. Collier, “Anticlines near Maverick Springs, Fremont County, Wyoming,” *U. S. Geol. Survey Bull.* 711 (1919), p. 159.

lists a marine fauna from it. Reeside¹¹⁷ and others have applied the term to Cretaceous strata as far north as southern Montana. Richmond,¹¹⁸ who mapped the Frontier formation in the northwest Wind River Mountains in Sublette County, Wyoming, states that "to the west the Frontier maintains its character across the Gros Ventre Range."

Thus, on the basis of lithologic similarity, of geographic distribution in relation to neighboring areas where Frontier strata have been described, and of faunal similarity, it seems justifiable to call this group of sandstone beds in the Mount Leidy Quadrangle, the Frontier formation.

Suggested correlation of the Frontier formation of the Gros Ventre River area with that of other regions is shown in Figure 9. Bartram¹¹⁹ also considers the Blackleaf and Mosley formations of Montana, the Codell of eastern Colorado, and the Ferron sandstone of Utah as Frontier equivalents.

CODY SHALE

General description.—The Frontier formation is overlain conformably by the Cody shale. The Frontier sandstones have been described as tan sandstones of which the more massive beds form ledges and cliffs and some of the more thinly bedded layers weather to flagstones. In contrast, the sandstones of the Cody are typically gray, nodular, and irregular. The shales of the Frontier are tan while those of the Cody are gray and black and commonly of the bony type, which weathers white. Numerous thin lignite beds are present throughout the vertical extent of the Cody. However, there is a zone of gradation between the Frontier and the Cody, and furthermore the contact between the two formations is transitional. There is some intermingling of the two types of sandstones and shales. The contact was arbitrarily chosen at the top of the highest Frontier type sandstone. Below it there are no lignite beds, but immediately above it a lignite series begins and the Cody type shales and sandstones predominate.

Because of the soft, easily weathered nature of the Cody shale, its characteristic topographic expression is a belt of low hills, bordered by the more resistant ledge- and cliff-forming Frontier sandstones below and the massive cliff-forming Mesaverde sandstone above.

The lower part of the Cody is a series of alternating gray sandstones, banded shales, gray clays, and thin lignite beds. This alternation accounts for the banded appearance as seen from a distance. Some of the shales weather whitish, resulting in the conspicuous light-colored bands.

About 475 feet above the base thin beds of nodular gray lithographic lime-

¹¹⁷ J. B. Reeside, Jr., "A New Fauna from the Colorado Group of Southern Montana," *U. S. Geol. Survey Prof. Paper* 132 (1923).

¹¹⁸ Gerald M. Richmond, "Geology of Northwest End of the Wind River Mountains, Sublette County, Wyoming," *U. S. Geol. Survey Prelim. Map* 31, Oil and Gas Invest. Ser. (1945).

¹¹⁹ John G. Bartram, "Upper Cretaceous of the Rocky Mountain Area," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 21, No. 7 (1937), p. 906.

stone first appear. Higher in the section, they occur more commonly. They weather to a characteristic rusty color. It is impossible to trace most of the beds of the Cody more than a few hundred feet horizontally because they are covered. The total thickness of the Cody shale is 1,365 feet in this area.

Detailed description.—The following section of the Cody was measured at Cole Hollow (Fig. 5) on the north side of the Gros Ventre River in the Mount Leidy Quadrangle, Teton County, Wyoming.

<i>Unit</i>	<i>Thickness (Feet)</i>
34. Sandstone, shale and limestone interbedded; not traceable as various beds become covered in short distances; several limestone beds, gray, weather rust to tan.	65
33. Sandstone, shale, and limestone; eight sandstone ledges; tan, weathering tan to reddish and rust color; shales and lignite interbedded; at least four ledges of dark gray lithographic limestone, weathers rusty; commonly occur just below sandstone ledges; limestone at top of ridge; ripple marks in sandstone.	268
32. Limestone, gray, weathers rusty; lithographic.	2
31. Covered; probably shale.	16
30. Sandstone, brown weathers tan; massive, but more thin-bedded at top; weathers cavernously.	9
29. Sandstone and shale; at base is sandstone, brown with white stain on surface; friable; forms ledge 3 feet high; covered interval above; probably shale overlain by sandstone ledge; brown, weathers reddish with white stain; shale above is covered, overlain by sandstone; weathers white and red-brown; thin-bedded; above are alternating shales and tan sandstone.	79½
28. Shale and lignite beds; in center a bright red-rust sandstone ledge.	26½
27. Sandstone, light gray, weathers tan; fine-grained; thin-bedded (average bedding ¼ inch); weathers platy; underlain by gray, fine-grained limestone; weathers tan-orange.	1
26. Sandstone, tan, weathers tan and reddish; friable; massive; overlain by woody shales; one and probably more lignite beds; several thin beds (1–3 inches) of limestone which weather rust-brown.	68½
25. Covered interval including shale, sandstone and lignite; shales are woody or bony; weathers rusty; in middle is thin gray sandstone, weathers platy; lignite beds.	34
24. Sandstone, gray, weathers reddish brown; thin-bedded; forms ledge.	2
23. Covered; at top gray lithographic limestone; weathers orange-tan; nodular.	9½
22. Sandstone, light tan, weathers light tan; thin-bedded; weathers to thin plates; distinct ledge.	1½
21. Shales, mostly brown, woody shale; several lignite beds; near top a gray calcareous shale; some sandy shale and sandstone.	91
20. Sandstone, gray, weathers buff with rust stain; ripple marks; forms definite ledge.	2
19. Sandstone and shale; sandstone at base of unit is gray, fine-grained, thin-bedded; forms gray ledge; woody shales and several lignite beds above with nodular gray lithographic limestone in center; weathers rusty-red.	84½
18. Covered tan clay slope; includes brown woody shale and lignite; petrified logs in lignite.	6½
17. Sandstone, light gray, quartzitic; forms ledge; blocky.	½
16. Shale, makes gray gumbo clay slope; contains nodules of gray, lithographic limestone.	83½
15. Lignite.	½
14. Sandstone, red, weathers buff.	½
13. Sandstone, gray, weathers gray-white; might be some interbedded shale.	45½
12. Shale, black, weathers white.	½
11. Lignite.	2
10. Shale, brown, woody.	2
9. Sandstone with yellow shale partings; weathers gray.	2
8. Sandstone and shale interbedded; base is tan, thin-bedded sandstone ledge; covered interval above, includes some black shale, probably lignitic; above is sandstone, tan, weathers brown with white stain; cavernous; massive; some fossil fragments; tan slope above, probably lignite bed and gray and brown shales; overlain by sandstone; weathers dirty green and reddish; olive-brown on fresh surface; above is another sandstone; weathers tan, whitish and brown on top of ledge; friable; fossiliferous; overlain by shale; at top is sandstone, tan; coarse-grained.	58½

Unit

Thickness
(Feet)

7. Shale, gray, some brown and woody and one or two coal beds; just above coal bed large <i>Ostrea soleniscus</i> weather out of brown shale.....	29½
6. Sandstone and shale; sandstone, gray, weathers gray and brown; friable, mostly thin-bedded; cross-bedded; near bottom is fossil zone containing <i>Ostrea soleniscus</i> , <i>Turbonilla coalvillensis</i> , <i>Turritella whitei</i> , <i>Mesostoma occidentalis</i> ; shale, mainly gray; some sandstone is nodular; several layers of interbedded lignite; top bed gray, ripple-marked sandstone; weathers to thin, smooth-surfaced plates.....	243½
5. Sandstone gray, weathers gray and brown; very friable at bottom; slightly more resistant above; fossil fragments of oysters or <i>Inoceramus</i> (only small fragments); some snails and a shark tooth; mostly thin-bedded; cross-bedded.....	38
4. Partly covered; tan gumbo; thin lignitic coal bed.....	38
3. Lignite, shale, clay, sandstone; lignite bed (10 inches) overlain by banded shale; layers of gray cherty material between shales; weathers light gray, but brown on fresh surface; gray material resembles porcellanite; ripple-marked on top (3 inches); above is clay, gray gumbo; may be bentonitic; sandstone above is light gray and very fine-grained; has black specks which may be of volcanic origin (6 inches exposed); unit makes conspicuous white bed on hillside; more clay above, tan gumbo; white beds at top somewhat like the white sandstone but more shaly.....	14
2. Sandstone and shale; sandstone weathers gray and very irregularly, almost nodular; gray brown on fresh surface; a few fossil fragments in some beds.....	15
1. Lignite ledge, weathers maroon; above is covered interval and then somewhat fossiliferous bed with small <i>Cardium</i> ; at top dark brown shale overlain by poor lignitic coal bed probably about 10 inches thick.....	25
Total thickness.....	1,365

The coal in the Cody shale is lignite or sub-bituminous. The thickest seam observed was 3-4 feet thick, but most of the seams are only 8-10 inches thick. Many of the seams have numerous clay partings. The thickest coal seams occur near the top of the formation.

Fossils.—Most of the fossils found in the Cody shale have come from the lower part of the formation. A bed in unit 1 contains *Cardium*, probably *Cardium pauperculum*. Unit 2 contains a few unidentifiable fossil fragments. Unit 5 contains oyster fragments, *Inoceramus* fragments and shark teeth. From unit 6 *Ostrea soleniscus* Meek, *Turbonilla coalvillensis*, *Turritella whitei* and *Mesostoma occidentalis* were identified. Just above the first coal bed of unit 7 is a brown shale containing many large specimens of *Ostrea soleniscus*. (These fossils were all collected at Cole Hollow on the north side of the Gros Ventre River about 1 mile above Upper Slide Lake.)

The stratigraphic position of other fossils found at scattered localities in the Cody is not known. Near the mouth of Lava Creek on the west side just north of the main Togwotee Pass highway about 20 feet above the creek and above an abandoned and caved-in coal mine were collected the following.

Arca (Barbatia) micronema (Meek)
Perna sp.
Pedalion sp., aff. *P. wyomingensis* Henderson
Unio sp.
Cardium pauperculum Meek
Volutoderma ambigua (Stanton)?
 Unidentified pelecypods
 Unidentified gastropods

About $\frac{1}{4}$ mile east of Lava Creek above a coal mine along the main Togwotee Pass highway the following fossils were collected.

Arca (Barbatia) micronema (Meek)
Ostrea soleniscus Meek
Lima? sp. A
Volsella multilinigera Meek
Cardium pauperculum Meek
Unidentified pelecypods

Origin of name and distribution.—The Cody shale was originally described from a rock section near Shoshone River which consists of gray and dark shale with one bed of sandstone near the base and several thin fossiliferous sandstones near the top.¹²⁰ It was named from the town of Cody which is located on an outcrop of the formation. The name was carried over from the Bighorn Basin to the Wind River Basin and later to the northwest end of the Wind River Mountains. The use of the term in this paper constitutes its westernmost application. Richmond¹²¹ has applied the term the farthest southwest to Cretaceous beds in the Green River area. It has been used as far north as southern Montana.

Age and correlation.—In the Bighorn Basin, the fauna of the Cody shale was shown by Stanton¹²² to be of Coloradoan and Montanan age. In the Oregon Basin, Reeside¹²³ found that the lower part of the Cody shale has a fauna like that in the Niobrara of the Great Plains and contiguous areas, and like that in the middle of the Mancos shale of New Mexico, Utah and Arizona and in the upper part of the Colorado formation of Montana; the upper 350 feet of the Cody has a fauna of Eagle age.¹²⁴

The fossils collected from the Cody in the Gros Ventre River area are not diagnostic. Such species as *Inoceramus umbonatus*, *Inoceramus exogyroides*, *Inoceramus deformis*, *Scaphites ventricosus* and *Scaphites vermiformis*, which Reeside considers to be good guide fossils for the lower Cody were not found. However, fossils are abundant at certain horizons in the Cody, and as a result, more extensive search will probably yield diagnostic fossils.

On the basis of stratigraphic position and lithology, it seems likely that the Cody in the Gros Ventre area corresponds in age with the Cody of the Bighorn Basin. The Cody of this area is probably correlative with the Hilliard formation of southwestern Wyoming. Among the fossils found by Schultz¹²⁵ in the Hilliard were *Ostrea soleniscus* and *Cardium pauperculum*, which are also found in the Gros Ventre River Cody. However, they are not diagnostic as both species commonly

¹²⁰ Charles T. Lupton, *op. cit.*, p. 166.

¹²¹ Gerald M. Richmond, *op. cit.*

¹²² Timothy W. Stanton, *op. cit.*, p. 120.

¹²³ J. B. Reeside, Jr., "Cephalopods from the Lower Part of the Cody Shale of Oregon Basin, Wyoming," *U. S. Geol. Survey Prof. Paper 150* (1927), p. 2.

¹²⁴ *Ibid.*, p. 1.

¹²⁵ Alfred R. Schultz, *op. cit.*, p. 65.

occur in the Frontier formation. The stratigraphic positions of the Cody and Hilliard are similar. Other correlations made with the Cody are shown in Figure 9.

MESAVERDE FORMATION

General description.—The Mesaverde formation overlies the Cody shale conformably. It is essentially a sandstone formation characterized by massive, buff-colored cliffs. Its total thickness in the area varies because of an unconformity at the top of the formation. The thickness along the Gros Ventre River near Cole Hollow is about 4,076 feet. This is probably about the maximum thickness for the region. The base of the Mesaverde formation was placed at the bottom of the first massive Mesaverde type sandstone which occurs above the highest lignite beds of the Cody.

Detailed section.—The following section of the Mesaverde formation was measured north of Cole Hollow in the Mount Leidy Quadrangle (Fig. 5).

Unit	Thickness (Feet)
13. (Beds are cut out in most places by unconformity.) Shales, at least two of the typical limestone beds and a slabby sandstone, weathering rust.....	100±
12. Sandstone, huge massive cliffs; appear white from distance; have typical brown ledge of sandstone on top.....	214½
11. Sandstone of same type as unit 12; probably forms huge cliff along side of ridge; near bottom of unit is calcareous gray sandstone and at bottom thin lignite bed.....	247½
10. Sandstone, perhaps a little interbedded shale; mostly massive with some thinner-bedded brown type as capping layers; nearly all are cliff-forming sandstones; some interbedded calcareous shales and probably black shales.....	1,400±
9. Partly covered, probably sandstone and shale; top of ridge is tan sandstone, weathers light gray; friable; overlain by gray sandstone which weathers brown and red.....	45½
8. Sandstone and shale; ledges of gray calcareous sandstone, weathers rust-brown; interbedded calcareous shales which weather gray and orange; top is massive ledge of gray sandy limestone, weathers rust-brown and reddish; weathered surface has cross-bedded appearance; 2 feet plus exposed.....	131½
7. Partly covered; consists of calcareous shales with ledgers of gray calcareous sandstone, weathers rust-brown; a little friable tan sandstone; a little plant material but not abundant as below; no cliffs like those of unit 2, just ledges, except at top of unit where there is cliff like those below; lignite bed 35 feet from bottom and another lignite bed a few feet above the first.....	190½
6. Partly covered; includes beds of gray, fine-grained calcareous sandstone, weathers rust-brown; some orange, calcareous shale; sandstones contain leaves and other plant fragments; thin lignite bed at top of unit.....	131½
5. Sandstone and covered; covered interval at base overlain by sandstone ledge lithologically like previous cliff; several outcrops of light sandstone above are capped by rust-brown sandstone; top is gray lithographic limestone, weathers orange-brown; thin-bedded, breaks into small fragments.....	90½
4. Sandstone cliffs separated by covered intervals; cliffs are of tan friable massive sandstone; weather cavernously; each cliff commonly capped by layer of darker brown, more thinly bedded sandstone which is in places dolomitic; a few ledges of dark gray sandy limestone, weathers rust-brown, are interbedded in shale; lignite bed near top of section.....	503
3. Unit appears somewhat transitional between 2 and 4; sandstone becomes more massive, cliff-former and lighter in color; however, there are still ledges of reddish-weathering, thin-bedded sandstone.....	150½
2. Sandstones, shales and limestone; long series of alternating sandstones, limestones, and shales; no fossils observed, and rocks seem lithologically same throughout; some sandstones and limestones stand out as ledges while shales and friable sandstone probably make up most of covered intervals between; limestone is dark gray, lithographic, in places nodular; weathers tan to rust-color; in places on weathered surface has irregular banding like woody structure; weathers into irregular pieces and commonly highly fractured; sandstones of two types; a gray friable massive bed which may make up	

Unit	Thickness (Feet)
some of covered intervals; it is ordinarily overlain by thin-bedded (average $\frac{1}{4}$ inch) gray, more resistant sandstone; commonly weathers with dark maroon color; shales observed were dark gray and tan-brown.....	837
1. Sandstone; two massive sandstone cliffs separated by short covered interval; lower part of each cliff is massive tan sandstone, capped by thin-bedded more resistant brownish-weathering sandstone; lower part of cliffs weather cavernously; at base of second cliff is brown woody shale overlain by a few inches of lignite.....	34
Total thickness.....	4,076±

Characteristic Mesaverde type cliffs.—The two massive sandstone cliffs of unit 1 are of a type characteristic of the Mesaverde. The lower parts of the cliff consist of massive buff sandstone. It weathers irregularly, and numerous caves and hollows are common along the cliff face. The cliff is capped by a thin-bedded more resistant sandstone which weathers brown. This harder layer commonly projects over the lower part of the cliff which is composed of the more easily eroded and much lighter-colored sandstone. Wherever the Mesaverde crops out, it may be recognized by cliffs, formed by the two contrasting sandstones.

Sedimentation cycle.—Unit 2 presents an interesting sedimentation cycle. It consists of 837 feet of alternating shales, sandstones, and limestones. The sandstones and limestones ordinarily stand out as ledges, and the shales make up the covered intervals between.

The sandstones in the series are of two types: one is gray, friable, massively bedded sandstone, and the other is gray, weathering dark maroon, thin-bedded, and more resistant to weathering. The thin-bedded, maroon-weathering sandstone ordinarily overlies the massive, gray sandstone. The shales, which make up the covered intervals between ledges of sandstone and limestone are dark gray and light brown. The limestone is dark gray and weathers tan to rust-color. It is lithographic in texture and in places nodular. It also shows, in places, on the weathered surface, an irregular banding, resembling woody structure. It is commonly much shattered and breaks with a tendency to conchoidal fracture.

In all, 68 alternating beds of sandstone, shale, and limestone were counted in this unit. The alternations follow the general pattern here listed. Approximately 14 such cycles are present.

Top	Thickness
Limestone, ledge, gray, nodular, lithographic.....	10-18 inches
Covered slope, probably gray and tan shales.....	10-20 inches
Sandstone ledge, gray, weathers maroon, thin-bedded.....	2- 8 feet
Sandstone, gray, massive, friable, commonly weathers to covered slope.....	10-15 feet
Bottom	

In order to account for these alternations the source of the sediments must be considered. It is believed that the highland which furnished the sediments was at the west because at the east the sandstones change to marine shales and because no Upper Cretaceous deposits are known in the Great Central Cordillera.¹²⁶

¹²⁶ J. B. Reeside, Jr., "Maps Showing the Thickness and General Character of the Cretaceous Deposits in the Western Interior of the United States," *U. S. Geol. Survey Prelim. Map 10*, Oil and Gas Inves. Ser. (1944).

The sandstone facies is generally considered to be mainly non-marine although in places there is interfingering of marine beds.¹²⁷ In the area described in this paper, no fossils were found in the beds belonging to the sedimentation cycle of unit 2, except a few plant fragments in one of the limestone beds near the top of the series of alternations. Leaves, other plant remains, and lignite seams have been found in higher units of the Mesaverde which probably indicate non-marine origin. Lignite seams also occur below unit 2. Ripple marks and cross-bedding are present in some of the sandstones. It seems likely therefore, that unit 2 is non-marine, although some of the beds may have had a marine origin.

PERIOD	NW. COLORADO BARTRAM	SW. WYOMING RICHMOND	SW. WYOMING SCHULTZ	GROS VENTRE MTS	CENTRAL WYOMING BARTRAM	BIG HORN BASIN LUPTON	BLACK HILLS S. E. WYO DARTON & BARTRAM
UPPER CRETACEOUS							
	MESAVERDE		— ? — ADAVILLE	MESAVERDE	MESAVERDE	MESAVERDE	PIERRE
	MANCOS	CODY	HILLIARD	CODY	STEELE	CODY	NIOBRARA
					NIOBRARA		
		— ? —			CARLILE		
		FRONTIER	FRONTIER	FRONTIER	FRONTIER	FRONTIER	GREENHORN
		— ? —					BELLE FOURCHE
		MOWRY AND THERMOPOLIS	ASPEN	MOWRY	MOWRY	MOWRY	MOWRY
							GRANEROS

FIG. 9.—Upper Cretaceous correlation chart.

The Gros Ventre River area is near the western margin of occurrence of the Mesaverde and its equivalents.¹²⁸ Thus the highlands furnishing the sediments may not have been far west. Wanless,¹²⁹ in discussing cyclic Pennsylvanian sediments, groups the cyclic sediments into three general types: the piedmont facies, the delta facies, and the neritic facies. The Mesaverde cyclic facies described here has certain similarities to the delta facies. Wanless¹³⁰ says that it is most typically

¹²⁷ *Ibid.*

¹²⁸ *Ibid.*

¹²⁹ Harold R. Wanless, "Sea Level and Climatic Changes Related to Late Paleozoic Cycles," *Bull. Geol. Soc. America*, Vol. 47, No. 3 (1936), p. 1182.

¹³⁰ *Ibid.*, p. 1184.

developed a few hundred miles from the high landmasses, which is the situation postulated for the Mesaverde. If the Mesaverde had been deposited nearer the landmass, some conglomerates and conglomeratic sandstones might be expected and none was found in unit 2. The order of the alternations in the Mesaverde is similar, in part, to the typical succession for the delta facies given by Wanless. At the base of the succession described by Wanless is a sandstone which is overlain by sandy shale grading upward into clay shale. This is overlain by impure limestone, generally non-fossiliferous and probably of non-marine origin. This much of the succession is very similar to that of the Mesaverde, although the rest of the series, which includes coal, is not present in unit 2.

Thus, the Mesaverde sediments may belong to a delta facies formed by material eroded from highlands a few hundred miles west. The cycles of deposition might have been due either to orogenic movements in those western highlands or to cyclic climatic changes. Uplift of the highlands on the west might have rejuvenated the streams resulting in the deposition of the sandstones. As the highlands became worn down, shale deposition replaced that of sandstone, and finally, when little or no clastic material was being brought in, limestones were laid down. These orogenic movements might have been forerunners of the Laramide orogeny which soon followed. It is difficult to explain a series of rhythmic orogenic movements. It seems more likely that the movements may actually have been progressive, rather than periodic. As effects of movements in the source region on distant sedimentation would not take place immediately, some cumulation of the effect might take place. Thus, progressive uplift might result in types of cyclic sedimentation.

The explanation of the sedimentation cycle by climatic changes is a possibility. The sediments are too thick to consider the cycles as due to seasonal or yearly changes. Climatic cycles of longer duration such as those indicated by repeated periods of continental glaciation might be responsible. Climatic cycles have been thought by some to be related to the sunspot cycle, precession of the equinoxes, and the eccentricity of the earth's orbit. Gilbert¹³¹ suggested that the 21,000-year period of the precession of the equinoxes was responsible for a rhythmic effect noted in Upper Cretaceous strata of Colorado. However, it is not at all certain how these various cycles affect the climate.

Upper part of Mesaverde.—Unit 3 is transitional between unit 2 and the overlying part of the Mesaverde. Its lithologic character resembles the cyclic repetition of unit 2, but the sandstones are more massive, and some form cliffs of lighter color. Above unit 3, this type of cliff-forming sandstone predominates and is most massive near the top of the formation. In some places the massive sandstones are overlain unconformably by the Pinyon conglomerate. In one place, above the massive sandstone, were found ledges of thin-bedded sandstone, shale, and limestone.

¹³¹ G. K. Gilbert, "Sedimentary Measurement of Cretaceous Time," *Jour. Geol.*, Vol. 3 (1895), pp. 121-27.

Origin of name Mesaverde.—The name Mesaverde was originally applied to a group of sandstone and coal beds in southwestern Colorado and northwestern New Mexico.¹³² Subsequently the Mesaverde formation was identified and mapped across central Wyoming. As Reeside states,¹³³ the name Mesaverde has been used rather widely as a designation for a coal-bearing series in the upper part of the Upper Cretaceous. The name has been applied as far away from the type area as northern Wyoming. Reeside further states that the relations of the Mesaverde group of southwestern Colorado to beds similarly named in northern Colorado, Utah, and Wyoming are not at all clear. In some parts of Wyoming the base of the Montana group is definitely known and general relations of the Mesaverde group of those regions to the typical Mesaverde can be deduced, but not enough faunal evidence has been assembled to make detailed comparisons possible.

Since no other than a few non-diagnostic plant remains were found in the Gros Ventre area, the term Mesaverde has been applied here in the same manner as in other parts of Wyoming, without any definite knowledge of its relationship to the type area in Colorado. The name, although not a good one, is used because this formation is lithologically similar to, and in approximately the same stratigraphic position as, the so-called Mesaverde of the Bighorn Basin and central Wyoming.

The Mesaverde may be related to the Adaville of southwestern Wyoming, which is also a coal-bearing formation. However, the Mesaverde in the Gros Ventre area does not have outstanding coal beds, but only a few very thin lignite seams. The Mesaverde occupies the same stratigraphic position as the Gebo and Meeteetse formations described by Hewett¹³⁴ which occur along the Shoshone River. It has also been correlated with the Judith River formation of Montana.¹³⁵ Further correlations are shown in Figure 9.

CONCLUSIONS

The Paleozoic and Mesozoic sedimentary rocks of the northern Gros Ventre and Mount Leidy Highlands area are relatively thin as compared with those laid down on the west and southwest. This indicates that the area was probably a shelf zone bordering a deeper part of the Rocky Mountain geosyncline during most of the Paleozoic and Mesozoic eras. It was not the location of any of the deeper basins which received great thicknesses of sediments. However, all of the systems, with the possible exception of the Silurian, are represented. The study

¹³² W. H. Holmes, *U. S. Geol. and Geog. Survey of Territories, Ninth Annual Report for 1875* (1877), pp. 245, 248.

¹³³ J. B. Reeside, Jr., "Upper Cretaceous and Tertiary Formations of the Western Part of the San Juan Basin, Colorado and New Mexico," *U. S. Geol. Survey Prof. Paper 134* (1924), p. 16.

¹³⁴ D. F. Hewett, "The Shoshone River Section, Wyoming," *U. S. Geol. Survey Bull. 541* (1912), p. 91.

¹³⁵ J. B. Reeside, Jr., *op. cit.* (1944).

of detailed stratigraphic sections of some of the formations resulted in the following conclusions.

1. Cambrian lithologic units and formations are persistent throughout the area and can be correlated with those of adjoining regions.
2. The so-called Bighorn dolomite may be a different formation from the type Bighorn; or, the Bighorn in western Wyoming may include more than one formation, and only part of the strata may be equivalent to the Bighorn farther east.
3. The Devonian rocks studied differ considerably in lithologic character where the sections were measured, and lithologic units could not be correlated.
4. The Frontier formation has a fauna similar to that found in the Frontier formation in other parts of Wyoming.
5. Upper Cretaceous rocks which are correlative with the Cody and Mesaverde formations of other parts of Wyoming are present.
6. The Mesaverde formation shows evidence of cyclic sedimentation.

